Lab Handout

Lab 16. Electrical Energy and Lightbulbs

How Does the Arrangement of Lightbulbs That Are Connected to a Battery Affect the Brightness of a Single Bulb in That Circuit?

Introduction

Scientists and historians generally agree that the approximately 250-year period from the 1550s to about 1800 was one of the most influential periods in history. During this time period—often referred to as the Scientific Revolution—science became increasingly important, and many of the people and developments of this period still influence our society today. For example, scientists such as Copernicus, Galileo, Kepler, and Newton published their most influential works during this time period.

While the ideas of Copernicus, Galileo, Kepler, and Newton (among others) are no doubt important and still remain influential, the most important development from this period may have come from a series of debates between Robert Boyle and Thomas Hobbes. Boyle was an important chemist and inventor. Hobbes was an influential philosopher. Boyle was a member of The Royal Society (along with Isaac Newton, Nicholas Mercator, and Edmond Halley, among many others), a scientific group that began in London during the 1600s (and the oldest scientific group still in existence). Hobbes was not a member of The Royal Society. Boyle and Hobbes had different views on how science should be conducted. Hobbes felt that science should be based on logic and reason, by which he meant that scientists should think about their questions and use philosophical approaches to answer those questions. This, said Hobbes, was how science had been done dating back to Aristotle. Boyle, on the other hand, suggested that science should be based on empirical results (a fancy term for evidence) and scientists should use rigorous investigative methods to answer their questions. Boyle also put forth the idea that scientists need to control for all the potential factors that might affect the outcome of an investigation (a more scientific way of saying that they should account for a factor by keeping it the same across conditions that are being tested). This, said Boyle, was how science should be done in the future, despite how it had been done in the past. After a series of debates and demonstrations, most of the members of The Royal Society sided with Boyle. The reliance on empirical support is what many scientists and historians say is the most important development of the Scientific Revolution.

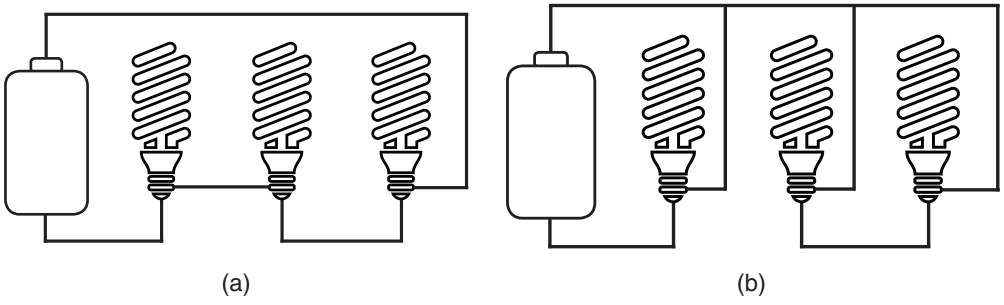
Another outcome of the Scientific Revolution was the development of new questions that scientists could investigate and attempt to answer. These questions gave rise to entire fields of science, such as microbiology and geology. A third field to develop during this time was the study of electricity—a field that is very much with us today. The study of electricity has led to the development of many important technologies that we still use today. In the year 1800, Alessandro Volta invented the battery. Another important invention due to the study of electricity is the lightbulb, invented by Thomas Edison in 1879.

One of the most difficult aspects of inventing a reliable lightbulb was identifying the best material to use for the filament in the lightbulb. The filament is a small wire inside the lightbulb that the electricity must pass through. When the electricity passes through the filament there is a lot of resistance, meaning it is difficult for the electric current to pass through the small wire. As the electric current moves through the filament, it generates heat energy due to the resistance of the wire (similarly to how your hands generate heat energy when you rub them together quickly) and that heat energy causes the wire of the filament to glow. During this process electrical energy is converted to radiant energy (or light energy).

Since the lightbulb and battery were invented, people have been investigating their behavior when they are connected as part of an electric circuit in many different ways. An electric circuit is a continuous path that allows electricity to leave a source (such as a battery), travel through wires and other objects (such as lightbulbs), and then return to the source. Research on batteries, lightbulbs, and circuits has shown that there are two general categories of ways to arrange lightbulbs in an electric circuit and connect them to a battery in a way that will still allow the bulbs to light. The two categories are called series circuits and parallel circuits. When lightbulbs are arranged in series, such as is shown in Figure L16.1(a), each bulb is connected to the next bulb and so forth. When lightbulbs are connected in parallel, such as is shown in Figure L16.1(b), each bulb is connected directly to the battery. The amount of light given off by a lightbulb is influenced in part by the strength of the battery (or other source of electricity) and the ways the lightbulbs are connected together. Scientists have investigated what happens to the brightness of the light emitted by the lightbulb when they are connected in series and parallel. In this investigation, you will have an opportunity to examine how the arrangement of bulbs connected to a battery in an electric circuit affects the brightness of a specific bulb in the circuit.

FIGURE L16.1

Bulbs in series (a) and in parallel (b)



Your Task

Use what you know about circuits, the relationship between structure and function, and how to design and carry out an investigation to develop a rule that will allow you to predict the brightness of a bulb based on how it is arranged in an electric circuit. During this investigation, you will want to keep in mind the ideas of Robert Boyle—that scientific rules need empirical support and it is important to control for all the factors that might influence your results during an investigation. Once you develop your rule, you will need to test it to determine if it allows you to predict the brightness of a bulb in a wide range of different circuits.

The guiding question of this investigation is, **How does the arrangement of lightbulbs that are connected to a battery affect the brightness of a single bulb in that circuit?**

Materials

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

- Size D batteries
- Battery holders
- Small lightbulbs
- Lightbulb holders
- Electrical wire
- Light sensor with interface
- 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. Use caution when handling bulbs, wires, and batteries. They can get hot and burn skin.
3. Never put batteries in your mouth or on your tongue.
4. Use caution in handling wire ends. They are sharp and can cut or puncture skin.
5. Lightbulbs are made of glass. Be careful handling them. If they break, clean them up immediately and place in a broken glass box.
6. Wash hands with soap and water after completing the lab activity.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

The first step in this investigation is to learn more about how the number and arrangement of bulbs in a circuit affect the brightness of a specific bulb in that circuit. To accomplish this

task, you must determine what type of data you need to collect, how you will collect it, and how you will analyze it before you begin.

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

- How will you determine brightness?
- What other factors, besides the type of circuit, could affect the brightness of a lightbulb?
- How will you control for those factors?

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:

- What factors will you compare to generate your rule?
- What type of table or graph could you create to help make sense of your data?

The second step in this investigation is to develop a rule that you can use to predict the brightness of a bulb in a circuit. Once you have your rule, you will need to test it to determine if it allows you to accurately predict the brightness of a bulb in several new circuits (ones that you did not use to develop your rule). It is important for you to test your rule, because the results of your test will not only allow you to demonstrate that your rule is valid but also will allow you to show that it is a useful way to predict the behavior of a lightbulb when it is connected to a battery and one or more other bulbs. Be sure to modify your rule as needed if it does not allow you to accurately predict the brightness of a bulb in a particular circuit.

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

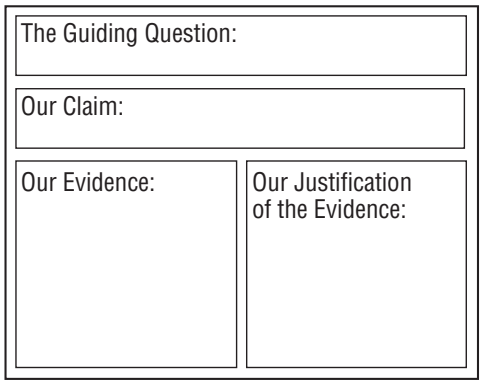
- the importance of tracking how energy and matter move within electrical systems,
- the relationship between structure and function in nature,
- the difference between data and evidence in science, and
- the nature and role of experiments in science.

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 L16.2.

FIGURE L16.2

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 your 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:

- What question were you trying to answer and why?
- What did you do to answer your question and why?
- 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!