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.

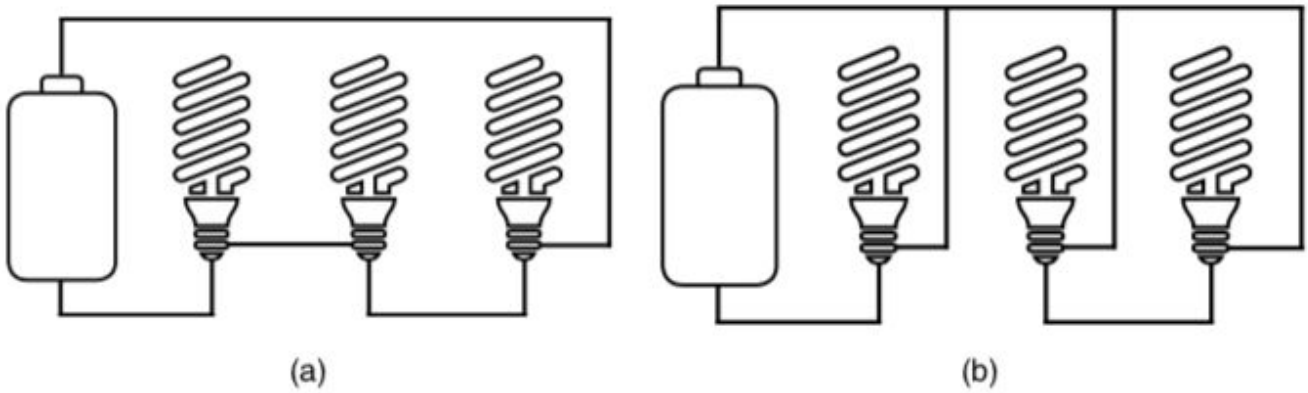
Another outcome of the Scientific Revolution was the development of new questions that scientists could investigate and attempt to answer. These questions gave rise to entire fields of science, such as microbiology and geology. A third field to develop during this time was the study of electricity—a 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 a series, [see figure below (a)], each bulb is connected to the next bulb and so forth. When lightbulbs are connected in parallel, [see figure below, (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.

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 can use the following link for the *Circuit Construction Kit* virtual lab during your investigation: https://phet.colorado.edu/sims/html/circuit-construction-kit-dc-virtual-lab/latest/circuit-construction-kit-dc-virtual-lab_en.htm

Getting Started
First, play around with the simulation to understand how to use it. You will need to understand how to make circuits with a battery, wires, and several lightbulbs as well as how to use the voltmeter and ammeter to measure voltage of the battery and current into it. You can record bulb brightness with descriptive language.

The next 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.

You should first test and record data for the following circuits in the simulation:

- One, two, and three lightbulbs in a series circuit (see figures 1, 2, and 3 below)
- One, two, and three lightbulbs in a parallel circuit (see figures 4, 5, and 6 below)

Figure 1

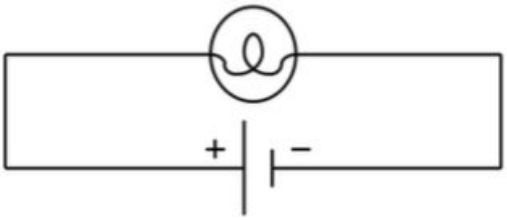


Figure 2

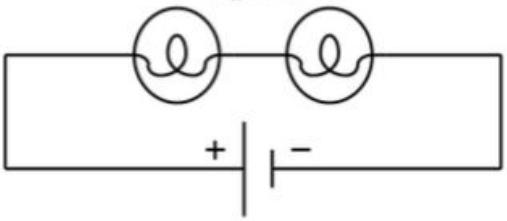
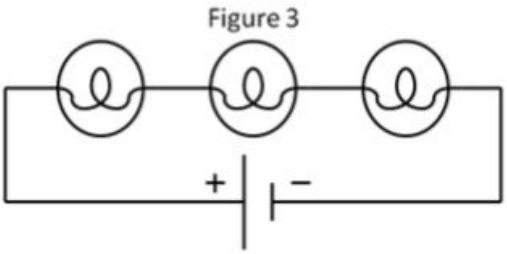


Figure 3



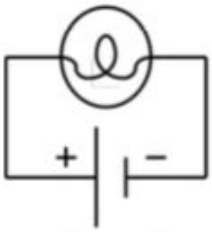


Figure 4

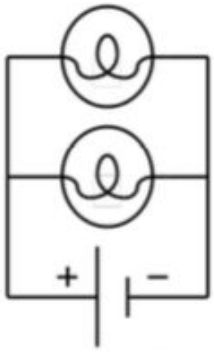


Figure 5

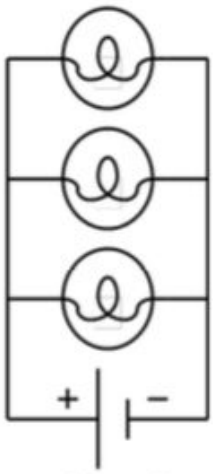


Figure 6

Here is an example data table you could use to record your results:

Type of Circuit	**Battery Voltage (V)**	**Current Out of Battery (A)**	**Brightness of Bulbs**
1 lightbulb, series			
2 lightbulbs, series			
3 lightbulbs, series			
1 lightbulb, parallel			
2 lightbulbs, parallel			
3 lightbulbs, parallel			

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.

Report

Once you have completed your research, you will need to prepare an investigation report that consists of four sections (be sure to have section headings):

1. Introduction: Give some background information on the topic. Explain what question you were trying to answer and include a hypothesis. (Background info, research question and hypothesis)
2. Procedure: What did you do during your investigation and why did you conduct your investigation in this way? (How you collected and analyzed data)
3. Data: Include a data table and/or graph to show your results. Be sure to include a title for your table or graph with labels for the variables.
4. Conclusion: What is your argument? (Claim - Evidence - Reasoning)

Your report should answer these questions in two pages or less. The report must be typed, and any diagrams, figures, or tables should be embedded into the document. Type your report on Google Docs (12 point font, double-spaced) and share it with your teacher. Your report will be graded based on the rubric in the class syllabus.