



This Little Light of Mine: Understanding Light Bulbs

By Tracy Empson

INTRODUCTION

This lesson will introduce students to the basic mechanics of how light bulbs work. Students will explore the different types of light bulbs available and the relationship between light, electricity, and heat. Finally, they will build their own flashlights and reflect on this process.

LESSON OVERVIEW

Grade Level & Subject: Grades 5-8: Science

Length: One class period

Objectives:

- Understand the relationship between light, electricity, and heat.
- Compare and contrast the fundamental differences of how light is created by incandescent, fluorescent, and diode technology

National Standards Addressed:

- **Content Standard: [NS.5-8.1 SCIENCE AS INQUIRY](#)**
As a result of activities in grades 5-8, all students should develop
 - Abilities necessary to do scientific inquiry
 - Understandings about scientific inquiry
- **Content Standard: [NS.5-8.2 PHYSICAL SCIENCE](#)**
As a result of their activities in grades 5-8, all students should develop an understanding of:
 - Properties and changes of properties in matter
 - Motions and forces
 - Transfer of energy
- **Content Standard: [NS.5-8.5 SCIENCE AND TECHNOLOGY](#)**
As a result of activities in grades 5-8, all students should develop:
 - Abilities of technological design
 - Understandings about science and technology
- **Content Standard: [NS.5-8.7 HISTORY AND NATURE OF SCIENCE](#)**
As a result of activities in grades 5-8, all students should develop understanding of:
 - Science as a human endeavor
 - Nature of science
 - History of science

Materials Needed:

- **Reproducible #1** – Incandescent Light Bulbs
- **Reproducible #2** – Fluorescent Light Bulbs
- **Reproducible #3** – LED Light Bulbs
- **Reproducible #4** – Comparing and Contrasting Light Bulbs
- **Reproducible #5** – Building a Flashlight
- **Reproducible #6** – Building a Flashlight: Reflection

For each lab group:

- 2 D cell batteries
- (2) 5" pieces of number 22 insulated copper bell wire with approximately 1" of insulation stripped off all ends
- Cardboard tube (toilet tissue or paper towel) cut to 4" in length
- PR6 3-volt flashlight bulb
- 2 brass fasteners (brads)
- 1" x 3" cardboard strip
- Paper clip
- Tape
- Small paper cup (like a Dixie cup)

Assessment: Students will be assessed through the following activities:

- Contributing to a group presentation about one of the types of light bulbs.
- Completing the worksheet that compares and contrasts the different types of light bulbs.
- Answering the reflection questions about the flashlight that they built.

LESSON STEPS

Warm-up: How Light Bulbs Light Up Our Lives

1. Begin this lesson by discussing with your class the role of electricity and light bulbs in modern life. Ask the following questions:
 - a) Before the invention of light bulbs, what did people use to create artificial (not from the sun) light? *Your students might discuss fire, candles, oil lamps and gas lamps.*
 - b) Why might light bulbs be considered superior to these forms other forms of artificial light? *Convenience, brighter light, longer lasting.* In what ways could these forms of light be considered superior? *Don't need electricity to function, lower carbon impact.*
 - c) Besides producing light, what else to light bulbs produce? *Heat.*
 - d) Can you think of any inventions that use light bulbs primarily for the heat they produce, rather than the light? *Incubators, Easy-Bake ovens, etc.*
 - e) Ask the class to list some activities that they engage in that would not be possible without light bulbs of some kind. *Watching TV, reading at night, using the computer, driving at night, etc.*

Activity One: Types of Light Bulbs

1. Break students into three groups and assign each group one of the following topics: (1) Incandescent Light Bulbs, (2) Fluorescent Light Bulbs, (3) LED Light Bulbs.
2. Provide each group with the information sheet that corresponds to their topic.
Reproducible #1—Incandescent Light Bulbs, Reproducible #2—Fluorescent Light Bulbs, Reproducible #3—LED Light Bulbs
3. Have each group read their information sheet. At the end of each information sheet is a set of guided reading questions. Ask students to discuss these questions among their groups and prepare to present their findings to the rest of the class.
4. Students present their findings to the class.
5. Individual Assessment: Pass out **Reproducible #4 - Comparing and Contrasting Light Bulbs**. Have students complete the worksheet individually.

Activity Two: Building a Flashlight

2. For this activity, break students into lab groups of three to five students. Each lab group will need a set of the materials listed at the beginning of this lesson plan.
3. Provide each group with **Reproducible #5: Building a Flashlight: Procedure**.
4. After all groups have built their flashlights, provide each student with a copy of **Reproducible #6: Building a Flashlight: Reflection** and have them complete it individually.

Conclusion:

After completing this lesson, students will have an understanding of the various types of light bulbs and how they compare to each other. They will also have built their own flashlight and will have reflected on the process, purpose and function.

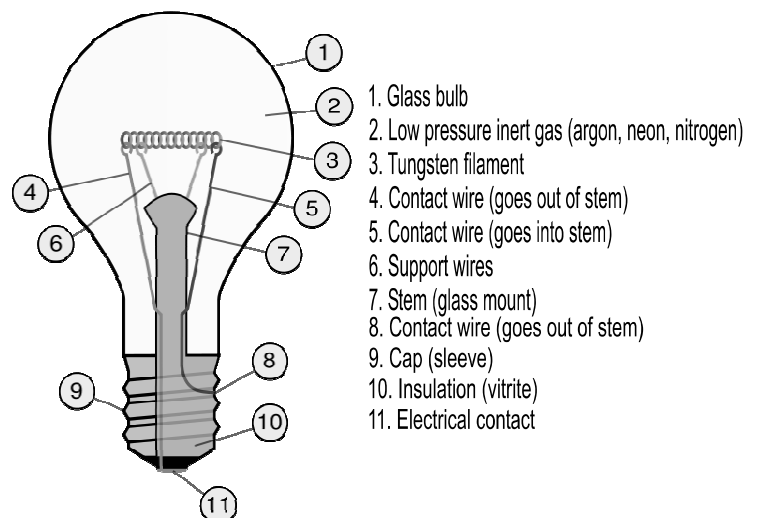
Incandescent Light Bulbs

History¹

Though numerous scientists contributed to the development of the light bulb, Thomas Edison (1847–1931) is most often credited with inventing the first practical incandescent bulb. Edison began researching the development of a practical incandescent bulb in 1878. He experimented with a variety of filament materials but ultimately settled on carbon. The first successful test was in 1879 and lasted 13.5 hours. Edison continued to improve this design and in November filed for a U.S. patent for an electric lamp using "a carbon filament or strip coiled and connected ... to platinum contact wires." Other scientists continued to develop the light bulb, introducing improvements in efficiency and production. Where Edison's first light bulb lasted only 13.5 hours, a modern incandescent bulb (60 watt) can last more than 1,000 hours! By 1964, improvements had reduced the cost of incandescent lights by a factor of thirty.

Structure²

“Modern incandescent light bulbs consist of a glass enclosure (the envelope, or bulb) with a filament of tungsten wire inside the bulb, through which an electric current is passed. Contact wires and a base with two (or more) conductors provide electrical connections to the filament. Incandescent light bulbs usually contain a stem or glass mount anchored to the bulb's base which allows the electrical contacts to run through the envelope without gas/air leaks. Small wires embedded in the stem in turn support the filament and/or its lead wires. The bulb is filled with an inert gas such as argon to reduce evaporation of the filament.”



Science

¹ Wikipedia. *Incandescent Light Bulb*. Retrieved 22 October, from http://en.wikipedia.org/wiki/Incandescent_light_bulb#Physical_characteristics

² Ibid.

Incandescent light bulbs, as the name suggests, are bulbs that work by incandescence. Incandescence is the emission of light from a hot body due to its temperature. A thin filament in the bulb is heated by an electric current until it produces light. Only 10 percent of the energy used by incandescent lights is converted to visible light, the other 90 percent is lost in the form of heat.

“When the bulb is hooked up to a power supply, an electric current flows from one contact to the other, through the wires and the filament. Electric current in a solid conductor is the mass movement of free electrons (electrons that are not tightly bound to an atom) from a negatively charged area to a positively charged area.

As the electrons zip along through the filament, they are constantly bumping into the atoms that make up the filament. The energy of each impact vibrates an atom -- in other words, the current heats the atoms up. A thinner conductor heats up more easily than a thicker conductor because it is more resistant to the movement of electrons.”³

Advantages and Disadvantages

Some advantages of incandescent bulbs are: (1) they are relatively easy to produce, (2) they are cheap to produce, (3) of all artificial light sources, they most closely resemble natural sunlight, and (4) they contain no toxic materials.

The major disadvantages of incandescent bulbs are directly related to their inefficiency. These disadvantages are: (1) 90% of the energy they consume is lost to heat, and (2) they contain filaments which burn out, reducing their life span.

Guided Reading Questions

- 1) **How many hours of light did Edison’s first incandescent bulb provide? How many hours will a modern incandescent bulb provide?**
- 2) **Why are incandescent bulbs filled with inert gas?**
- 3) **How do incandescent bulbs produce light?**
- 4) **What is incandescence?**
- 5) **What is electric current?**
- 6) **What are the advantages of incandescent bulbs? Disadvantages?**

Challenge Question: Are incandescent bulbs efficient at producing light? Why or why not? (Hint: Think about how much energy is converted into light)

³ *How Light Bulbs Work*. Retrieved 22 October 2008, from <http://home.howstuffworks.com/light-bulb1.htm>

Fluorescent Light Bulbs

History⁴

Although Arthur Compton, a renowned physicist and GE consultant, reported the first successful experiment with fluorescent lighting in 1934, there were several key scientific developments that led to this success.

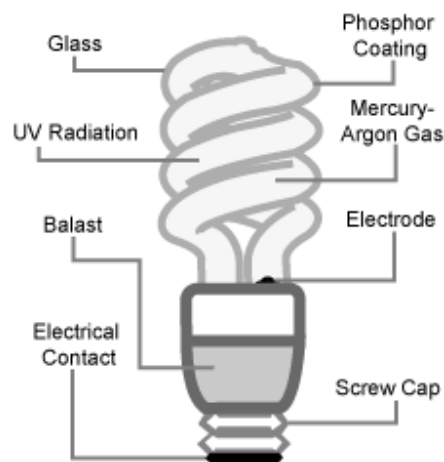
The first of these discoveries was the Geissler tube, created in 1856 by German glassblower Heinrich Geissler. Geissler created a mercury vacuum pump that evacuated a glass tube to an extent not previously possible. When an electrical current passed through a Geissler tube, a strong green glow on the walls of the tube could be observed.

The second important development was the mercury vapor lamp, invented by Peter Cooper Hewitt in 1901. The lamp lit up when an electric current was passed through mercury vapor at a low pressure. Fluorescent tubes would later be filled with mercury vapor.

In 1909 the French chemist Georges Claude observed the red glow that was produced when running an electric current through a neon-filled tube. The development of the neon light gave rise to the fluorescent coating later used in fluorescent bulbs. All three of these discoveries contributed to the structure of the modern fluorescent light.

Structure⁵

Fluorescent light bulbs consist of a glass tube filled with a gas containing mercury vapor and argon. The inner surface of the tube is coated with phosphor coating. The bulb's electrode, through which electricity flows, is typically made of coiled tungsten. Fluorescent lamps must use a device called a ballast to regulate the electric current flow through the tube.



Science

Fluorescent light bulbs use electricity to excite the mercury vapor within a glass tube. The phosphor coating on the glass absorbs the energy released by the excited mercury atoms, causing the phosphor to fluoresce, producing visible light. Fluorescence is a process by which substances give off light when they absorb energy. This means that the visible light given off by a fluorescent bulb does not come from the mercury atoms, rather it comes

⁴ Wikipedia. *Fluorescent lamp*. Retrieved 23 October 2008, from http://en.wikipedia.org/wiki/Fluorescent_lamp

⁵ Ibid.

from the phosphor which lights up when it absorbs the energy from the excited mercury atoms.⁶

Fluorescence is a form of luminescence or light not generated by high temperatures alone. This means that a higher percentage of the energy consumed by a fluorescent light is converted to light as opposed to heat. Whereas an incandescent bulb only converts 10 percent of its energy to light and loses 90 percent in the form of heat, fluorescent bulbs convert 85 percent of energy to light and lose only 15 percent to heat.⁷

Advantages and Disadvantages

Some advantages of fluorescent bulbs are: (1) 85% of the energy they consume is converted directly to light, (2) they do not contain a filament that can burn out, and (3) they are able to produce more light using less energy than their incandescent counterparts.

Some disadvantages of fluorescent bulbs are: (1) they contain mercury vapor, which is toxic, (2) it takes time for the bulbs to reach their full intensity, (3) the color of the light they produce is not as close to natural sunlight as other types of bulbs, and (4) fluorescent lights cannot be dimmed.

Guided Reading Questions

- 1) **What were the three scientific discoveries that led to the development of the fluorescent light bulb?**
- 2) **Fluorescent lights are the only type of bulbs to use a ballast. What is the function of the ballast?**
- 3) **How do fluorescent light bulbs produce light?**
- 4) **What is fluorescence?**
- 5) **What is luminescence?**
- 6) **What are the advantages of fluorescent bulbs? Disadvantages?**

Challenge Question: Are fluorescent bulbs efficient at producing light? Why or why not? (Hint: Think about how much energy is converted into light)

⁶ Wikipedia. *Fluorescent lamp*. Retrieved 23 October 2008, from http://en.wikipedia.org/wiki/Fluorescent_lamp

⁷ Energy Star. *Compact Fluorescent Light Bulbs*. Retrieved 23 October 2008, from http://www.energystar.gov/index.cfm?c=cfls.pr_cfls

Light-Emitting Diode (LED) Light Bulbs

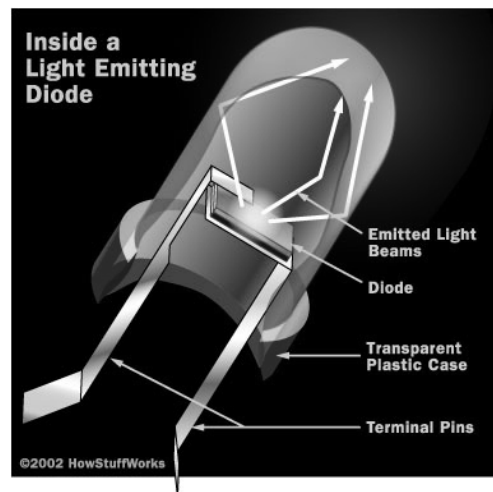
History⁸

There is no one true inventor of the light-emitting diode (LED). The various colors of LEDs were all developed by different scientists. The so-called father of the light-emitting diode is Nick Holonyak Jr. Holonyak developed the first practical visible-spectrum (red) LED in 1962 while working at General Electric Company. The first yellow LED was invented in 1972 by M. George Craford, a former graduate student of Holonyak's.

In 1991, Shuji Nakamura of Nichia Corporation of Japan demonstrated the first high-brightness blue LED. The development of blue LEDs and high efficiency LEDs led to the development of the first white LED. In 2006, Nakamura was awarded the Millennium Technology Prize for his invention. Advances in optics and material science have led to an exponential increase in LED efficiency and light output, with a doubling occurring about every 36 months since the 1960s. Modern LEDs can last up to 100,000 hours and use up to 90% less energy than incandescent bulbs.

Structure

The structure of a light-emitting diode is fairly simple. It is comprised of metal terminal pins connected to a source of electricity. Electricity flows through these terminal pins to the diode to which they are connected. The diode produces light in the form of photons (you'll read more about that later). The entire device is housed in a transparent plastic case that concentrates the light in one direction.



Science⁹

A diode is the simplest sort of semiconductor device. Broadly speaking, a semiconductor is a material with a varying ability to conduct electrical current. Most semiconductors are made of a poor conductor that has had impurities (atoms of another material) added to it. The process of adding impurities is called doping. In doped material, additional atoms change the balance, either adding free electrons or creating holes where electrons can go. Either of these additions makes the material more conductive.

A semiconductor with extra electrons is called N-type material, since it has extra negatively-charged particles. A semiconductor with extra holes is called P-type material, since it

⁸ *Light Emitting Diode*. Retrieved 23 October 2008, from <http://en.wikipedia.org/wiki/LED>

⁹ *How Light Emitting Diodes Work*. Retrieved 27 October 2008, from <http://electronics.howstuffworks.com/led1.htm>

effectively has extra positively-charged particles. A diode comprises a section of N-type material bonded to a section of P-type material, with electrodes on each end.

When the negative end of a circuit is hooked up to the N-type layer and the positive end is hooked up to P-type layer, electrons and holes start moving. As free electrons moving across a diode fall into empty holes from the P-type layer, they release energy in the form of light. The color of the light depends on how far the electrons fall.

Advantages and Disadvantages

Some of the advantages of LEDs are: (1) they require very little energy compared to other types of bulbs, (2) they don't have a filament that can burn out, and (3) they are incredibly long lasting, (4) they contain no toxic substances, and (5) their small size makes them flexible.

The main disadvantage of LEDs is that it is not currently practical to use them to produce high levels of room lighting. As a result, current LED screw-in light bulbs offer either low levels of light at a moderate cost, or moderate levels of light at a high cost. Additionally, LED light tends to be concentrated in one direction, which makes it difficult to light an entire room with LEDs.

Guided Reading Questions

- 1) Who developed the first practical visible-spectrum LED? What color was it?
- 2) What is N-type material? P-type material?
- 3) How do LEDs produce light?
- 4) What is a diode? What is a semiconductor?
- 5) What effect does doping have on the semiconductor?
- 6) What are the advantages of LEDs? Disadvantages?

Challenge Question: Are LED bulbs efficient at producing light? Why or why not?

Comparing and Contrasting Light Bulbs

- 1) Describe how each type of bulb produces light:

Incandescent: _____

Fluorescent: _____

Light-Emitting Diode: _____

- 2) List one advantage and one disadvantage for each type of light bulb:

Incandescent: _____

Fluorescent: _____

Light-Emitting Diode: _____

- 3) When looking at light bulbs, what factors contribute to a bulb's efficiency or inefficiency? _____

- 4) Which type of bulb is the most efficient? Explain your answer. _____

- 5) Replacing inefficient lighting with more efficient lighting can save your school energy and money. List some places in your school where you could install more efficient lighting. What types of bulbs would you use? _____

Building a Flashlight: Procedure¹⁰

Safety Warning

Though you will be working with low-voltage batteries, it is important to exercise caution during this activity:

- Improper wiring can result in battery leakage and/or rupture. Carefully follow wiring instructions for each experiment.
- Contact with internal battery material can cause injury. DO NOT disassemble a battery.

Materials Needed:

- 2 D cell batteries
- (2) 5" pieces of number 22 insulated copper bell wire with approximately 1" of insulation stripped off all ends
- Cardboard tube (toilet tissue or paper towel) cut to 4" in length
- PR6 3-volt flashlight bulb
- 2 brass fasteners (brads)
- 1" x 3" cardboard strip
- Paper clip
- Tape
- Small paper cup (like a Dixie cup)

Procedure:

Step 1: Create the on/off switch for your flashlight by pushing the brass fasteners through the cardboard tube and attaching the paper clip to one of the fasteners. The fasteners should be positioned so that the paper clip can touch both of them.

Step 2: On the inside of the tube, attach a wire to each fastener. The unattached ends of the wires should stick out of either side of the cardboard tube.



¹⁰ Graphics for this activity provided by Energizer. <http://www.energizer.com/learning-center/science-center/Pages/make-flashlight.aspx>

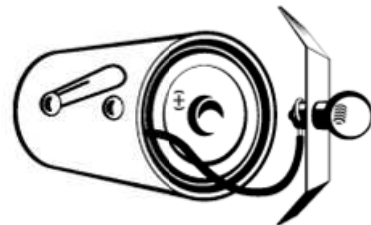
Step 3: Tape the batteries together, (+) to (-), and slide into the tube.

Step 4: Tape one end of the wire securely to the negative (-) end of one of the batteries.



Step 5: Cut a hole (large enough to insert the flashlight bulb) in the center of the cardboard strip.

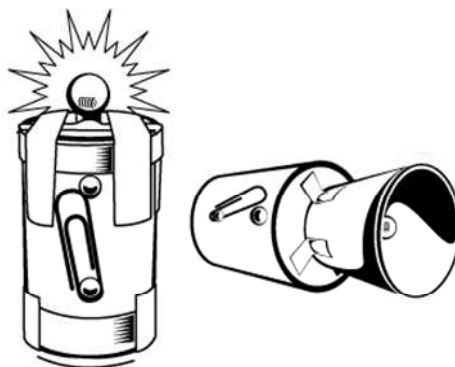
Step 6: Wrap the wire around the base of the bulb and insert the bulb into the hole in the cardboard strip.



Step 7: Tape the cardboard strip to the tube, positioning the bulb for contact with the positive (+) end of the battery.



Step 8: The paper cup will act as a reflector. Cut a hole (large enough to insert the flashlight bulb) in the bottom of the cup. Insert the bulb through the hole and secure with tape.



Step 9: Now touch the paper clip to the other fastener and watch your flashlight light up!

Building a Flashlight: Reflection

- 1) What purpose do the batteries serve in the flashlight that you built?

- 2) What is the function of the copper wire in the flashlight?

- 3) Why does the insulation need to be stripped from the ends of the copper wire?

- 4) When you touch the paperclip to the brass fastener, the light bulb lights up. Explain why this happens.
