

Circuits 1

Materials

Playful Penguin Race Toy (assembled, and with D battery installed)

CR 2032 Coin batteries (one or two per student)

LEDs (three or four per student, assorted colors)

Double-sided foam tape

Masking tape

Alligator clip leads

Paper fasteners 2 boxes of 100 each

Small binder clips – box of 100

Cardstock -- 65 # wt. or greater, assorted colors

Scissors

Post-it® squares

Materials for testing as conductors or insulators (in addition to those listed above): buttons, coins, fabric, paper, aluminum foil, plastic wrap, pipe cleaners, chalk, crayons, washers, etc.

Readings

Petzold, Ch. 4

Handouts:

What are Waves?

What is Light?

Resources

Electrocity https://www.citytechnology.org/energy_systems/electrocity/ Pp. 10-15 & 29-43

Lucas: What is Visible Light? <https://www.livescience.com/50678-visible-light.html>

1. Batteries and LEDs Distribute LEDs and coin batteries.

Individual Activity: Turn on the LED. Keep track in your notebook of the following:

a) What do you notice about the battery and the LED?

b) When you try to turn it on, what works and what doesn't work (use diagrams).

c) What limits are there when you try to light more than one LED from the same battery?

Students are likely to discover that the battery can light up multiple LEDs of the same color, but some colors will not light up together. For example, if you light up a blue LED, and then add a red one, the blue one will turn off.

d) Which combinations will light up together, and which ones will not?

2. Models

If you were able to make the LED light up, you created an electric circuit. How does it work? Unfortunately, we can't see inside the circuit to answer that question. However, a common strategy for understanding a system that is too small, too big, or otherwise invisible to create a model of it. A model is more manageable than the real thing because it omits the aspects that get in the way of understanding and focuses only on the essential features. In Computer Science the technique of modeling is called abstraction or information hiding. In science and engineering, there are all kinds of models, such as diagrams, maps, 3D models and mathematical equations that are supposed to capture the essence of the system. Children use models too, because the real thing is too big, too vulnerable, or too small to use.

Class activity: Scavenger hunt for models used by children, in the classroom or elsewhere. For each model, list the real thing it represents, what is similar between the model and the real thing and what is different. For example, a doll represents a person, both have similar body parts, but the doll is usually smaller, made of different materials, and definitely not alive! A globe represents the earth, but has many fewer features, and is much smaller.

3. Penguin Race Toy

This toy provides a useful model of an electric circuit. Ask the class the following questions:

- In a circuit, what do you think is traveling around?
- In the toy, what do you see traveling around?
- In a circuit, what gives the electrons the energy they need to light up the LED, and what kind of energy is it?
- In the toy, where do the penguins get their energy, and of what kind is this energy?
- What would happen to the penguins if you disconnected one end of the ramp from the stairway? What would happen in the circuit if only one wire from the LED were attached to the battery?
- If you wanted to give the electrons more energy, what could you do? How could you change the stairway to give the penguins more energy?

Develop the idea that the Penguin Race toy is a model of an electric circuit. You can't see the electricity in the circuit, but in the toy, you can see the penguins. Even though they are different, the toy can help you think about what's happening in a circuit.

- In a circuit, **voltage** measures how much energy the electricity is carrying and how much it can do. You can increase the voltage by adding batteries. In the toy model, what plays the role of the battery? What would you have to do to increase or decrease the voltage?
- In a circuit, **current** measures how much electricity is flowing. In the toy model, what plays the role of the current? What would I have to do to increase or decrease the current?

Class activity: Complete a comparison chart showing the analogies between an electric circuit and the penguin toy (see Table 1, below).

Table 1: Penguin Toy vs. Electric Circuit

Issue	Penguin Toy	Electric Circuit
What is traveling around the loop?	penguins	electrons
What keeps them in line?	the ramp	the wires
What gives them the energy they need?	the stairway	the battery
What kind of energy is it?	gravitational	
How do they lose this energy to another form?	by rolling down the ramp	by lighting the LED
How could you increase the energy?	make the stairway higher	add another battery
Measuring the energy per moving object	Height of ramp	voltage
Flow rate of moving objects	Penguins/ minute	current

4. Why do some LEDs not work together?

LED stands for Light Emitting Diode. A diode is a device that can conduct electricity in only one direction – somewhat like a fire exit that you cannot enter. This is the reasons why it will not turn on unless the long (+) wire of the LED is attached to the + side of the battery, and the short wire to the – side. Another property of a diode is that when it conducts, it limits the voltage across it. However, this limit is different for LEDs of different colors.

We have seen that voltage is a measure of the energy per electron supplied by a battery or other source of electricity. The last piece of the puzzle is about visible light, which is a form of electromagnetic radiation, which consists of a wave traveling through space with rapidly oscillating electric and magnetic fields. Like any wave, light has a frequency, a measure of– how rapidly the fields bounce up and down. As frequency increases, wavelength – the distance between the crests – goes down. Different colors of light have different frequencies and wavelengths. We’ll learn a lot more about light in the second course.

A consequence of quantum theory is that higher wave frequencies carry more energy. In the spectrum of visible light, red has the lowest frequency, and therefore requires the least energy to produce, while blue has among the highest frequencies, and therefore requires the most energy. Because energy is proportional to voltage, this help to explain why a red LED will turn off a blue LED, when both are connected to the same battery. The red LED cuts off a lower voltage, preventing the voltage from rising to the higher level needed to turn on the blue LED.

Question for discussion:

- Besides blue and red, what other LED combinations won’t turn on together?

- Using the spectrum and the chart of wavelengths or frequencies of each color, explain why some combinations of LEDs can light up together from the same battery, while others can't.

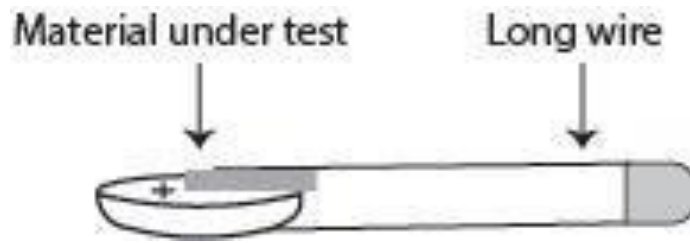
BREAK BETWEEN SESSIONS

5. Conductors and Insulators

Some materials can conduct electricity, while others cannot. Make a list of the available materials and predict which ones will conduct electricity. Then test each one by

Individual activity

Make a list of the available materials and predict which ones will conduct electricity. Then test each one by inserting it between the long wire of the LED and the plus side of the battery, as shown below. How will you be able to tell if the material is a conductor or an insulator?



6. Switch Hunt

Nearly every electrical appliance has a component that has been missing from the circuits we made. You must be able to turn it on or off. The device that does this is a switch, which is the basic control element in an electric circuit. We'll study controls in depth later in this course.

Class activity: To get an idea of the variety of switches, let's conduct a scavenger hunt for switches – switch hunt for short. For each switch you list, identify also what it controls, where you find it and how you operate it. List only switches that you operate by hand. Do not include switches that work automatically such as the switches that turn on the refrigerator light or the dome light in a car. The list should include switches that you operate in different ways, such as by turning something, flicking it pushing down or sliding. Table 2 will get you started.

Table 2: Switch Hunt

Where can you find it?	What does it control?	How do you operate it
Entrance of the room	lights	Flick it

7. Make a switch. A switch works by touching two conductors together to turn something on, and separating the conductors by air, an insulator, to turn it off.

Looking at the results of the Switch Hunt, it should be clear that some switches stay in place after you operate them, while others need to be held in place. Some switches must be rotated, while others are operated by sliding them, pushing down or perhaps pulling a chain. The names of common switches are shown in Table 3. You can create most of these kinds of switches yourself using paper fasteners and binder clips.

Table 3: Basic Switch Types

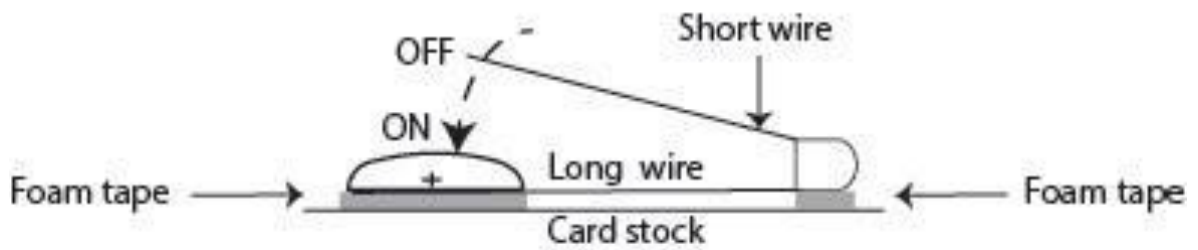
Type of switch	How you operate it	Typical use
Push button	Push and hold it down	Keyboard
Toggle	Flick it	Light switch
Rotary	Turn it	Electric fan
Slide	Slide it	Penguin toy

Group activity: Using cardstock, paper fasteners and binder clips, create each of the four types of switches listed in Table 3. For hints and suggestions, see Table 4 below.

8. Insert a switch in a circuit

Now that you have a switch, you can add it to a circuit to control a LED. The word “switch” does not really reveal much about what it does or how it works. A more expressive word is the Spanish word for switch, *interruptor*, which suggests that the role of the switch is to interrupt the current. The switch should be put in a position where it breaks the flow of electricity when it is in the OFF position and restores the following when it is ON.

The simplest idea is to use one of the wires of the LED as a pushbutton switch. Here is a diagram:



Group activity: Insert your switch into the circuit so it can turn the LED ON or OFF.

Table 4: Ideas for making simple switches

Type	Materials	How to make it	
Push-button	Two paper fasteners, cardstock	Attach the fasteners so that the leg of one can be pushed down to touch the head of the other, and so this same leg will spring back up when released.	
Rotary	Two paper fasteners, cardstock	Push both fasteners through the cardstock, about an inch apart. Keep one leg of one fastener on top. Rotate this leg so it is touching the top of the other fastener to turn the circuit on, and away to turn it off.	
Slide	Three paper fasteners, cardstock	Cut a slot for one paper fastener, and poke holes for the other two. Mount two paper fasteners through the holes with heads up and mount the third through the slot with both legs up. The legs turn the circuit ON by touching the two heads, and OFF by sliding away from them.	
Toggle	Binder clip, two paper fasteners, cardstock	Mount the paper fasteners about a half inch apart and place the bulldog clip so its handle can touch both fasteners. Use the snap action of the bulldog clip handle to turn the circuit ON and OFF.	

9. Schematic diagrams

How can we represent the circuits we have made? A drawing or diagram is another kind of model because it shows what's important without including details that do not really matter.

Individual activity: Make a drawing of your circuit.

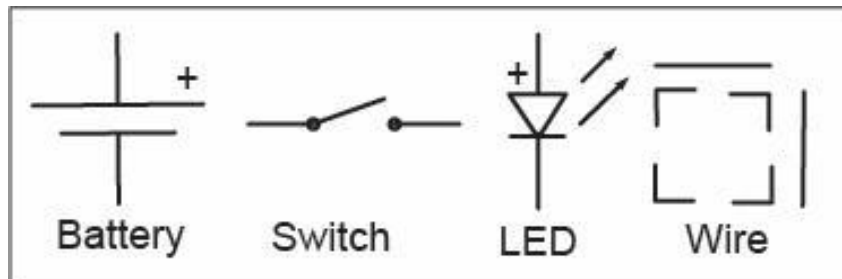
Gallery walks: Post all the drawings and ask the class to examine each one. They can use post-its to write comments or observations.

Class discussion:

- What did you notice about the drawings?
- How were they different?
- What features make a circuit drawing easier to understand?
- Could you reproduce the circuit using only the drawing?

Develop the idea of a common visual language that everyone could use to understand each other's circuits. Engineers, who design circuits for a living, have developed such a language, which they use to create schematic diagrams. The language includes both symbols for representing circuit components, and rules for arranging them in the diagram. The symbols used in schematic diagrams are yet another example of a code, and the key to this code is shown below.

Key to circuit symbols used in schematic diagrams



The rules for arranging the symbols are another form of standardization, which make a schematic diagram easy to read at a glance. A person who reads a lot of these diagrams will be able to find things quickly, because the lines will be straight, and the components will be where they are expected.

Rules for Making Circuit Diagrams

- Use horizontal or vertical straight lines to represent wires between circuit parts.
- Use square corners between horizontal and vertical lines.
- Put the battery on the left and the LED on the right.
- Put switches on top.

Individual activity: Using the standard symbols and rules, create a schematic diagram that represents your circuit.

Gallery walks: Post the diagrams and repeat the gallery walk.

Class discussion:

- How is a diagram different from a drawing?
- What are the pros and cons of using diagrams instead of drawings?
- How well did the diagrams follow the rules?
- How would you correct them?
- What information does a diagram leave out, which a drawing might include?
- How important would this information be to someone trying to understand your circuit?
- How important would it be to someone trying to reproduce it?