Fundamentals of Engineering
Final Project
11/2/12
Leah Ritz

Tin Foil Circuit Board: ***Lie Detector***

Teacher Background:

The Tin Foil Circuit Board activity introduces students to the basic concepts of electrical engineering and the processes and tools involved in electrical engineering projects, including soldering and populating circuit boards with electrical components. Science concepts to be learned include electricity as the movement of electrons, the parts of a basic circuit (input, output, and continuous loop), series versus parallel circuits, switches, how various components can be used to alter electricity flow, and how Ohm's Law can help us mathematically explain how resistors affect the flow of electricity, which we see as a change in the output.

This activity is especially relevant to students in the technological age because most of what people use on a day-to-day basis for communication and entertainment has evolved to use a circuit board. Electrical engineering is incredibly important in today's society. The Tin Foil Circuit Board lends itself to a discussion on the evolution of the technology and how computers have changed from filling entire rooms to being able to fit in our pockets while still accomplishing hundreds more tasks. One of the major advantages of circuit boards is that it makes circuitry a little more manageable by replacing wires with etched copper lines. Manufacturing engineering has advanced to the point where we can now produce circuit boards on a micro scale. In addition, a discussion of microchips and circuit boards can include a discussion on all the ethical implications of computers and the Internet - safety and privacy, environmental concerns, changing cultures and social behavior.

The Tin Foil Circuit Board is an important introductory activity because it is extremely relevant to daily life. It acts as an interesting and accessible gateway into understanding how technology works through simple materials while opening up the discussion on changing technology and how and why we use it. These specific science and math concepts are important to learn and apply to a hands-on project because they are the building blocks for more complicated projects.

Student Outcomes and Assessment:

Students will understand that electricity is a flow of electrons through a circuit that includes a power input, a continuous loop of conductive material, and an output (light, sound, or work). They will know that one important measure we have for electricity is voltage. Students should understand the difference between series and parallel circuits and how switches are able to open and close circuits. They will understand that electricity can be altered by electrical components and will know that resistors are one of the ways that we can change the flow of electrons. Students will also understand that there are laws that were discovered that help us learn and talk about electricity. They will know that Ohm's Law helps us explain how resistors alter the flow of electricity by changing the current flowing through the circuit.

Science:

Standard:	Benchmark:	How this project meets the standard:
3.1.1.2.3	Maintain a record of observations, procedures and explanations, being careful to distinguish between actual observations and ideas about what was observed.	Recording observations from testing parallel vs. series circuits, values of resistors, and how they affect the brightness of light

Standard:	Benchmark:	How this project meets the standard:
4.1.2.2.1	Identify and investigate a design solution and describe how it was used to solve an everyday problem.	How circuit boards were developed and how they affect day-to-day life
4.1.3.3.1	Describe a situation in which one invention led to other inventions.	Advancement of technology related to circuit board manufacture
4.2.3.2.2	Construct a simple electrical circuit using wires, batteries, and light bulbs.	Testing different types of circuits
5.1.1.2.2	Identify and collect relevant evidence, make systematic observations and accurate measurements, and identify variables in a scientific investigation.	Recording observations from testing parallel vs. series circuits, values of resistors, and how they affect the brightness of light
6.1.2.1.1	Identify a common engineered system and evaluate its impact on the daily life of humans.	How circuit boards were developed and how they affect day-to-day life.
6.1.2.1.2	Recognize that there is no perfect design and that new technologies have consequences that may increase some risks and decrease others.	How circuit boards and their applications have changed over time.
6.1.2.1.3	Describe the trade-offs in using manufactured products in terms of features, performance, durability, and cost.	How does a homemade tin foil circuit board compare to a manufactured circuit board?
6.1.3.4.1	Determine and use appropriate safe procedures, tools, measurements, graphs, and mathematical analyses to describe and investigate natural and designed systems in a physical science context.	Testing the relationship between values of resistors and brightness of LED
6.2.3.2.2	Trace the changes of energy forms including thermal, electrical, chemical, mechanical or others as energy is used in devices.	Different outputs for circuits including light, sound, and work.
7.1.1.2.2	Plan and conduct a controlled experiment to test a hypothesis about a relationship between two variables..	Testing the relationship between values of resistors and brightness of LED
8.1.3.3.3	Provide examples of how advances in technology have impacted the ways in which people live, work, and interact.	How advances in producing circuit boards have changed the way people live and work.

Math Standards:

Discussion of Ohm's Law address math standards on multiplication and division, algebra, variables, and equations including:

3.1.2B Multiplication and division
4.1.1A Multiplication and division facts
4.1.1B Multi-digit multiplication

5.1.1 Division
5.2.3 Equations and inequalities
6.1.3A Multiplication and division
6.2.1 Variables and representation of relationships
6.2.3 Represent and solve equations
7.2.1 Proportional relationships
7.2.2B Solving proportional problems
7.2.4 Represent and solve equations
8.2.3 Algebraic expressions

Students will demonstrate that they understand these concepts by being asked to construct a circuit board out of cardboard, tin foil tape, and electrical components - 9V power supply, 2 LEDs, 1K resistor, and a buzzer. Students will begin by discussing the invention of circuit boards and how they have shaped the world as we know it. They will then work through two exploratory exercises including series vs. parallel circuits and testing different values of resistors. Student participation in discussion will also indicate the extent of student comprehension.

This activity is designed to be an introduction to circuit boards, which are used in many of Tronix Team's more complicated projects. As a result of completing this activity and understanding these concepts, students will be able to build and identify these applications in more complex circuit boards. In the more complex circuit boards, students should be able to trace circuits through different electrical components and be able to explain how some electrical components control or alter electricity flow.

Lesson Structure:

This lesson is designed to be taught in Tronix Team informal after-school science enrichment programs around Minneapolis, but can easily be adapted to a formal classroom setting in order to address any of the standards listed above. This activity can be adapted to suit students in grades 3-8 and can take 1-2 sessions to complete (1.5-3 hours). The exploratory part of this activity is to guide students in discovering different aspects of circuit design (series vs. parallel circuits and Ohm's Law). Students will then apply these concepts to the construction and understanding of a simple model circuit board.

This lesson is a combination of our introductory lessons to circuits and electricity flow and our advanced circuit board construction projects to give all program participants a thorough introduction to why circuit boards are used, how they work, and how they have evolved over time, as well as a more thorough introduction to electrical components and how to populate a circuit board with them. Often in our classes for older students, they jump right into building circuit boards without the groundwork on how or why they work while the younger students get a lot of how and why the circuits work without being able to apply them to some of the functions they see every day (circuit boards).

Challenges and Misconceptions:
Electricity, as an intangible and invisible substance, is very hard to explain and for many students to understand on the first try. Topics that may need extra attention include:

- The "continuous loop" aspect of a circuit and how it is still continuous when we put things like switches and other electrical components into it.
- Identifying the physical difference between parallel and series circuits. Be sure to refresh students on what the word "parallel" means.
- Students often think the batteries or light bulb are dying or burned out when we put resistors in the circuit. Take extra care in explaining the concept of resistance in a circuit.

Creating circuit boards can be quite challenging to the spatial reasoning of some students. Be prepared to address the following during this project.

- Translating the image of the circuit board pattern to the circuit board.
- What side of the circuit board to populate.

- Identifying a circuit or continuous loop out of the disconnected pieces of tin foil tape.

Constructing a Tin Foil Circuit Board:

**Students will complete projects individually but will work in partners during the preparatory part of the lesson to encourage more exploration.

Materials:
- Tin foil tape
- Cardboard (cut in 4" x 4" squares)
- Brad fasteners
- Paper clip
- Red and Green LED
- Buzzer
- 9V battery and snap
- Christmas lights (Exploratory Activity 1)
- AA batteries and holder (Exploratory Activity 1)
- Resistors - 1K, 10K, 100K
- Scissors
- Awl, X-acto knife, or other tool for poking holes
- Exploratory Activity worksheets

Preparation:
- Solder short wires onto the legs of the Buzzer to make them longer and more bendable. This will make them easier to install in the circuit board.
- Cut strips of tin foil tape approximately ¼" wide and 4" long
- Example circuit boards from common electronic devices for demonstration purposes

Procedure:
Day 1:
- Parallel and Series Circuits Activity
- LEDs and Resistors Activity
- Introduce Tin Foil Circuit Board
- Trace circuit board pattern on cardboard

Day 2:
- History and Context
- Construct - Poke holes, brad fasteners, install components

**Blue, italicized writing indicates instructor explanation or discussion topics.

Exploratory Activity 1: Parallel vs. Series circuits

1. Introduce electricity and circuits. Electricity is a type of energy that we use for all type of useful jobs. It's not really that useful unless we can control it by running it through circuits. There are 3 parts to a circuit: Input (battery), Output (light), a Continuous Loop (wire).

2. Have students construct a simple circuit using Christmas lights and AA batteries/battery pack.

3. Hand out worksheet with different light configurations. Have students work independently through the configurations and record the brightness of the light bulb(s).

4. When students have mostly finished the worksheet, review the results--how bright were the lights in each configuration?

5. Discussion: *When the Electricity flows through a light bulb, it uses a little bit of energy to light the bulb, and when it comes out, there is less energy coming out than going in.*

In Series Circuits: If less comes out to go into the next bulb, there is less energy to light the second bulb. In the second bulb, a little more energy gets used up and there is even less that comes out that's available for the next bulb.

In Parallel Circuits: When the bulbs are next to each other, the same big amount of energy goes into each light bulb at first because none of it has been used up by light bulbs in front of it.

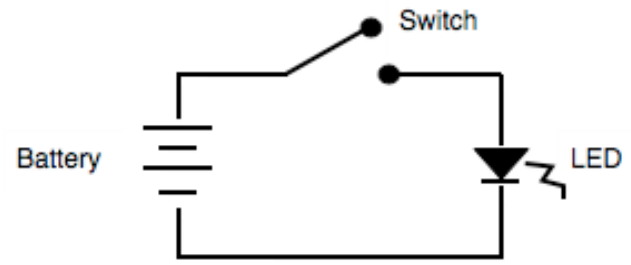
Demonstration: Pour four glasses of water. Glass 1 = battery, pretend to be a light bulb and take a drink, then pour it into the next glass. Is there the same amount of water in the second glass? Continue through a few glasses and see how the water (energy) changes.

Exploratory Activity 2: Ohm's Law - How we can alter the flow of electricity using resistors.

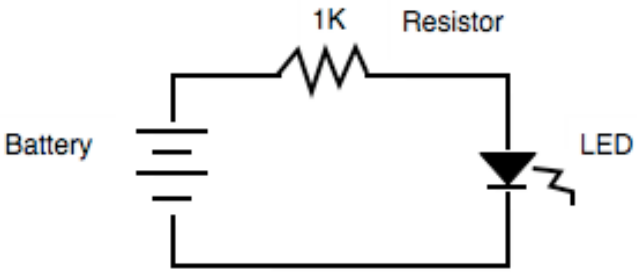
How to control light:

The amount of light that comes out of the circuit can be controlled by changing the amount of electricity that flows through a circuit. We can change how bright a light is in a series circuit by adding more light bulbs. In a circuit with one bulb, all the electricity is going to the light bulb and the light is as bright as it can be.

Even if we put in a switch to open and close the circuit, when the circuit is closed, all the electricity is still flowing to the battery and the light bulb is shining as bright as it can.

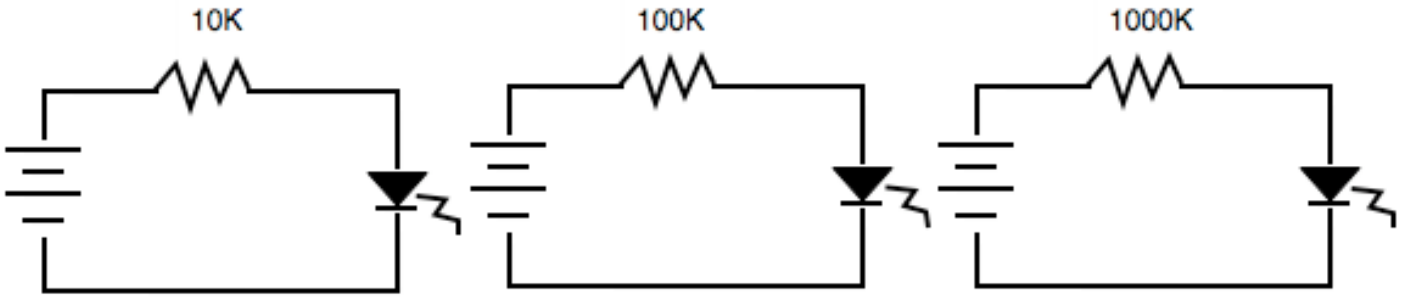


A simple electrical component that we can put into this circuit to help control the amount of electricity is called a resistor. What can you guess a resistor would do based on the root word "resistor"?



Resistors are measured in Ohms. What happens when we put in a 1 K Ohm resistor, or a resistor that measures 1000 Ohms of resistance?
The result should be that the light bulb is not as bright.

Make a prediction about what would happen if we used a 10K, 100K, or 1000K Ohm resistor. Test your prediction by using these resistors to replace the 1K resistor and complete the circuit above. Record the result on the Controlling Electricity worksheet.

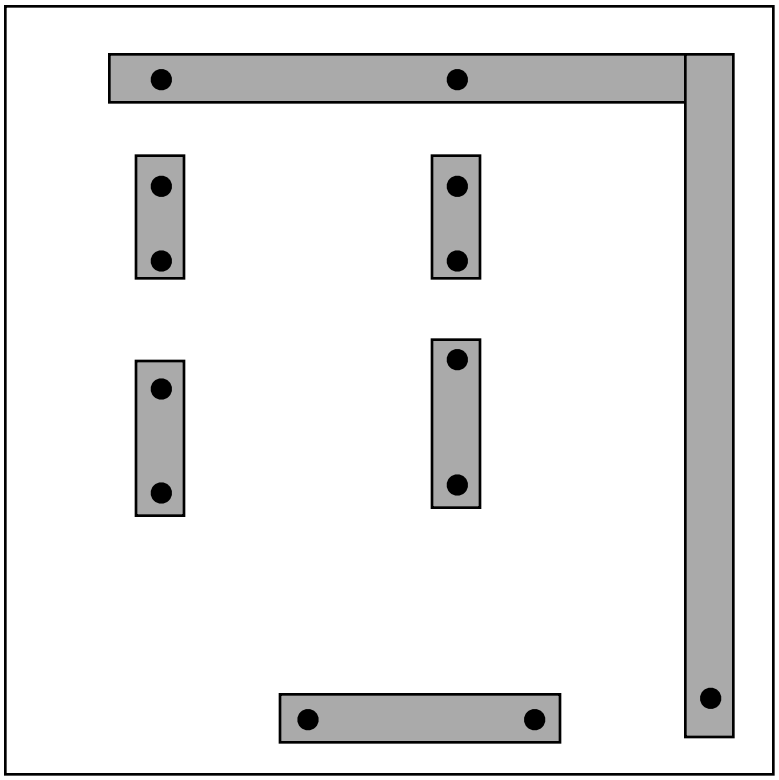


Prediction:	Prediction:	Prediction:
Result:	Result:	Result:

Application Activity: Tin Foil Circuit Board - Red Light, Green Light or Lie Detector

History and context: What is a circuit board, what does it do, and why are we making one?
Circuit boards are an advancement in technology that helps us control electricity for doing useful things for us. A circuit board is made of a pattern of etched copper lines that act kind of as a roadmap to connect different electrical components. The components and the order they are arranged change the way that electricity functions. Advances in manufacturing and technology allow us to make smaller and smaller circuit boards and components. Where have you seen circuit boards before? What are their applications? What are some of the advantages of using circuit boards in electronics?

Construction:
1. Transfer the circuit board pattern onto the cardboard:



2. Cut strips of tin foil tape to the right length and press them down firmly on the circuit board pattern.

3. Poke holes (black dots) in the circuit board using a sharp tool (awl, x-acto knife, sharp pencil etc.)

4. Insert brad fasteners through the blank cardboard side so the legs stick out onto the side with the tin foil tape. *Discussion: Why do we put things through on the blank side and not the side with the tape? Because it is easier! This simulates what we do when building real circuit boards because we can only put solder on the side with the metal.*

5. Insert LEDs into the circuit board so that the negative leg (short wire) is facing the top of the board. Red light on the left, green light on the right. Bend the legs over and use small pieces of tin foil tape to firmly press the legs down onto the piece of tape where the leg sticks out.

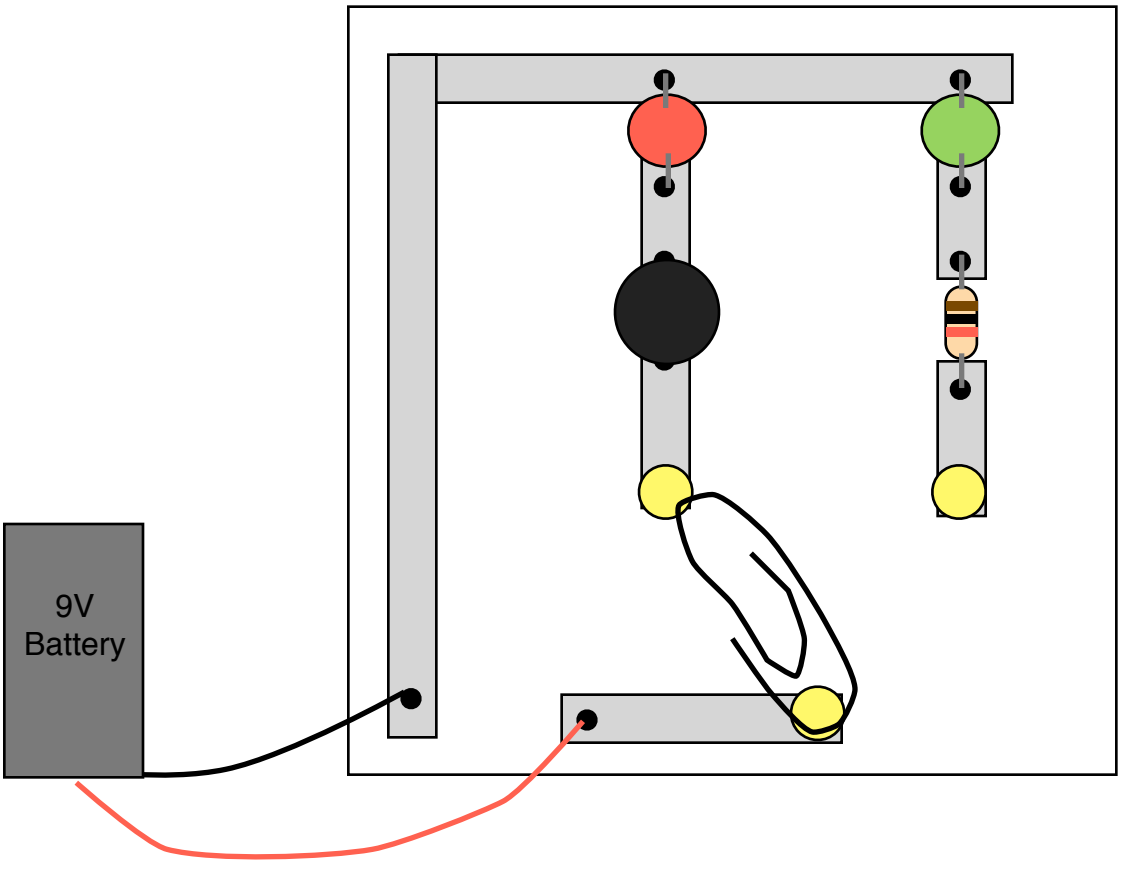
6. Insert the Buzzer under the red LED so that the negative leg is closest to the red LED and the positive leg is on the bottom side of the board. Bend the legs over onto the tin foil tape where they stick out and use small pieces of tape to press them down firmly.

7. Insert the 1K (brown, black, red) resistor under the green LED. Bend the legs over onto the tin foil tape and use small pieces of tin foil tape to press them down firmly.

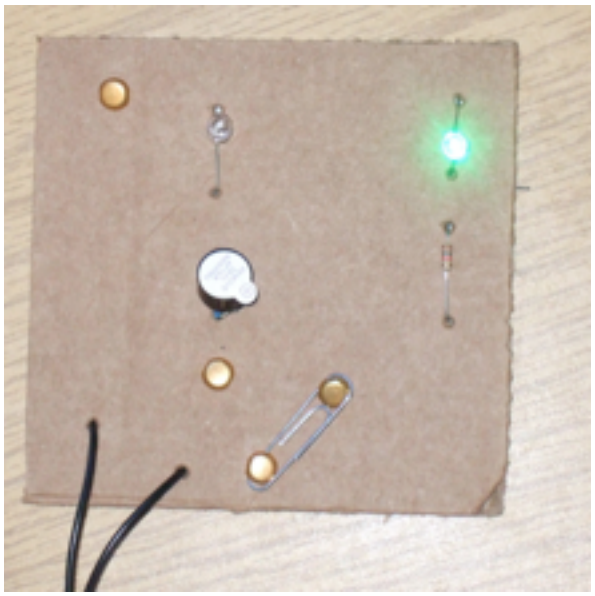
8. Insert the black (negative) wire from the battery snap into the corner of the circuit board. Bend the legs over onto the tin foil tape and use small pieces of tin foil tape to press them down firmly.

9. Insert the red (positive) wire from the battery snap into the circuit board by the triangle of brad fasteners that will become the switch. Bend the legs over onto the tin foil tape and use small pieces of tin foil tape to press them down firmly.

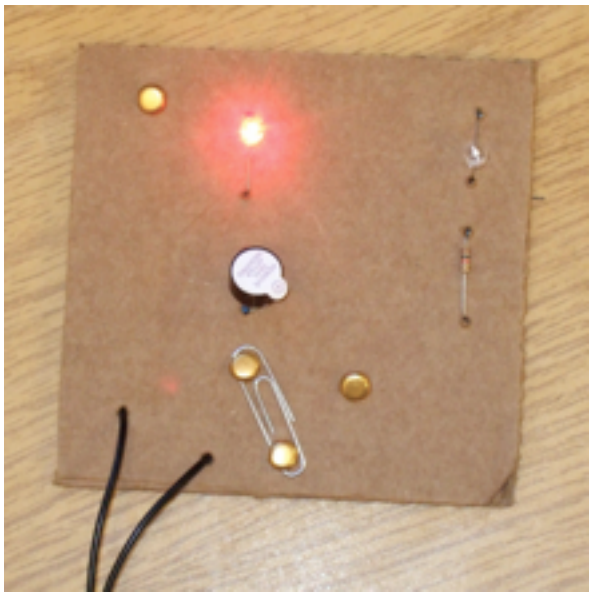
10. Slide a paper clip under the bottom point of the triangle. The paper clip should be able to swing back and forth between the other two brad fasteners to turn on the green and red light/buzzer.



11. Attach the battery and test! What can you use the Tin Foil Circuit Board for? What can a red and green light be used for? True/False, Stop/Go etc.



Go / True



Stop / False

Reflection Questions:

- How is this like a manufactured circuit board?
- What are the electrical components used on this circuit board? (LED, Buzzer, Resistor, Switch)
- Trace a circuit from start to finish, including the electrical components. How many circuits can you find? Where is an example of a series circuit? Where is an example of a parallel circuit?
- What would happen if we took out the resistor?
- Why does one circuit use a resistor (Green light) while the other one doesn't (Red light)?
- What would happen if we touched a paper clip to the switch for the Red and Green light at the same time?

How it Works:

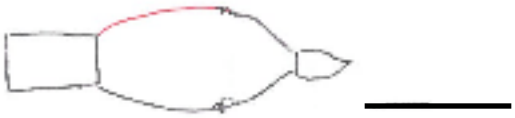
There are two series circuits, in parallel on this circuit board. The switch turns on only one series circuit at a time, but could turn on both, in parallel, at the same time if we used two paper clips. The Green circuit includes the resistor and green LED while the Red circuit includes the buzzer and the red LED. LEDs can only handle about 3V of electricity so the Green LED needs the resistor to prevent the light from burning out. The red light doesn't need a resistor because the Buzzer provides enough resistance that the LED won't burn out. We use 9V instead of 3V because the Red light circuit with the Buzzer does not turn on with only 3V of electricity.

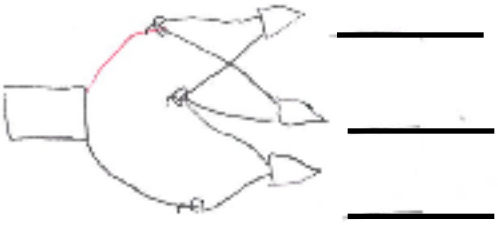
Worksheets:

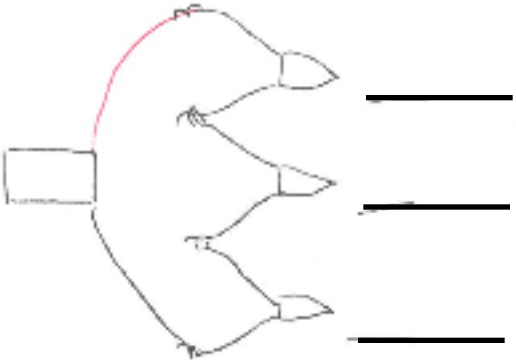
- Parallel and Series light bulbs
- Ohm's Law predictions - Controlling Electricity

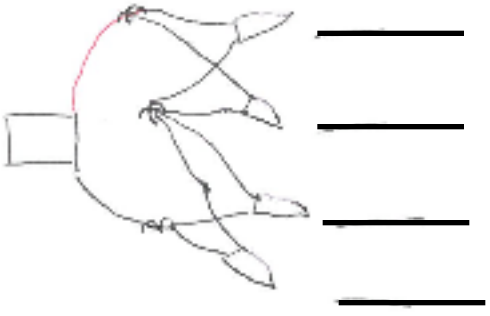
Series and Parallel Circuits Worksheet

Make each arrangement of light bulbs below. Write what happens to each light bulb in the space next to it. B for bright, D for dull.







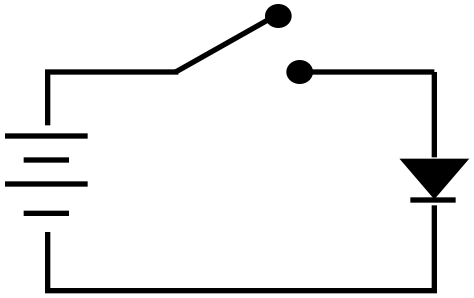


BONUS!!
Can you think of any other arrangements? What are the results?

Controlling Electricity Worksheet

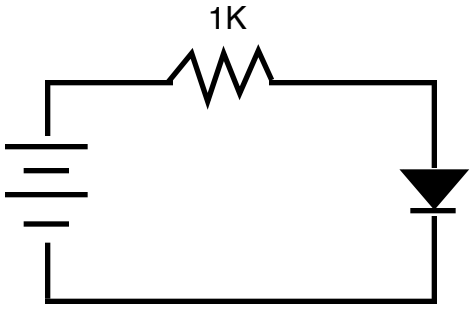
Light energy is an output of an electrical circuit. The amount of light that comes out of the circuit can be controlled by changing the amount of electricity that flows through a circuit. In the most basic circuit, all the electricity is going to the light bulb and the light is as bright as it can be.

Even if we put in a switch to open and close the circuit, when the circuit is closed, all the electricity is still flowing to the battery and the light bulb is shining as bright as it can.



A simple electrical component that we can throw into this circuit to help control the amount of electricity is called a resistor. What can you guess a resistor would do based on the root word “resistor”?

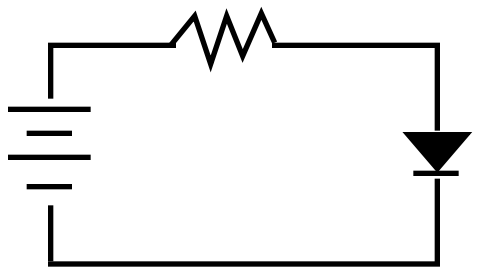
Resistors are measured in Ohms. What happens when we put in a 1 K Ohm resistor, or a resistor that measures 1000 Ohms of resistance?



The result should be that the light bulb is not as bright.

Directions: Make a prediction about what would happen if we used a 10K, 100K, or 1000K Ohm resistor. Test your prediction by using these resistors to replace the 1K resistor and complete the circuit above. Record the result.

10K



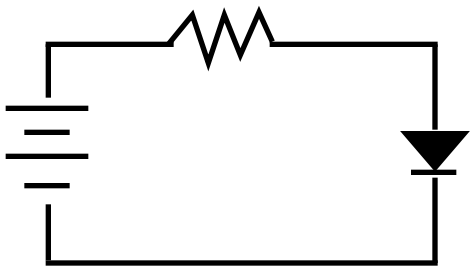
Prediction:

_____

Result:

_____

100K



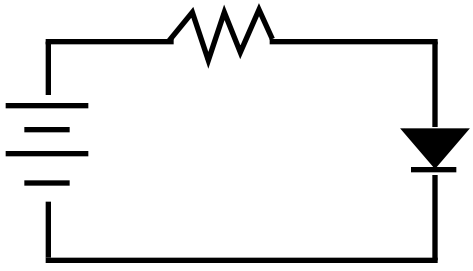
Prediction:

_____

Result:

_____

1000K



Prediction:

_____

Result:

_____

What do these results mean about how we can control electricity?

_____

_____

_____