CLASSE INSTITUTE FOR PHYSICS TEACHERS (CIPT)

Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)

Title:	**Notebook Circuits With Metering (Middle School)**
Original: **Revision:** **Modified for CLASSE:**	22 February 2007 14 July 2009 March 2014
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Appropriate Level:	Intermediate Level Science, Physical Science
Abstract:	Students are introduced to concepts of electrical energy and electrical current using a paper model. They construct simple circuits using inexpensive household items and explore their behavior. Next they meter series and parallel circuits, and extract relationships for series and parallel circuits from their data. A series of questions leads students to consider energy transformations that occur in the electrical circuits they constructed.
Time Required:	Two to three 40-minute periods
NY Standards Met:	4.1d Different forms of energy include heat, light, electrical, mechanical, sound, nuclear and chemical. Energy is transformed in many ways. 4.4e Electrical circuits provide a means of transferring electrical energy. 4.4f Without touching them, material that has been electrically charged attracts uncharged material, and may either attract or repel other charged material.

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Behavioral Objectives:

Upon completion of this lab a student should be able to:

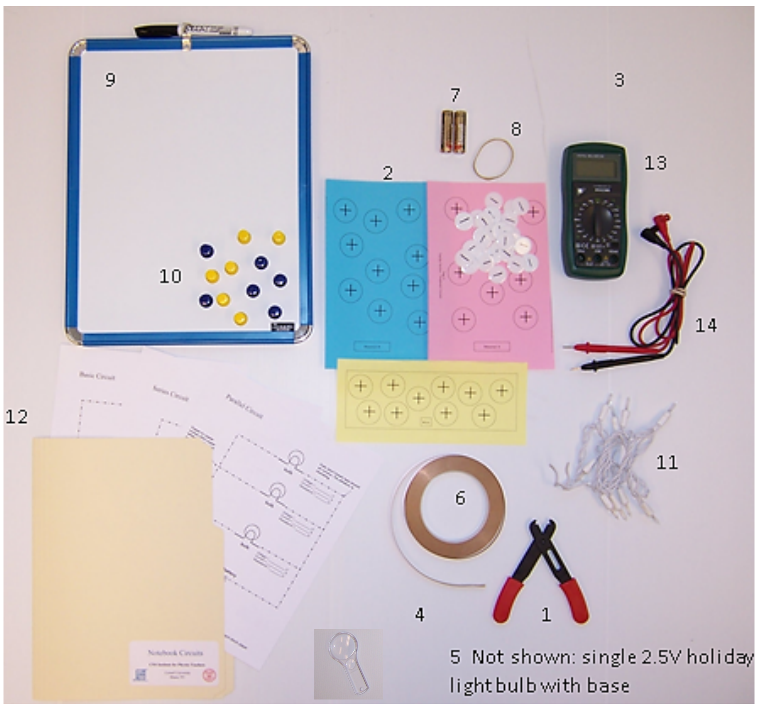
- To introduce concepts of electrical energy and electrical current
- To learn about the transformation of electrical energy in a circuit
- To learn that a complete circuit is required for current to flow
- To construct simple series and parallel circuits
- To gain familiarity with circuit diagrams

Class Time Required: Two to three 40-minute periods

Teacher Preparation Time: 5-10 minutes to set out supplies

Answers to Questions: *send email to cipt_contact@cornell.edu to request answers.*

Equipment

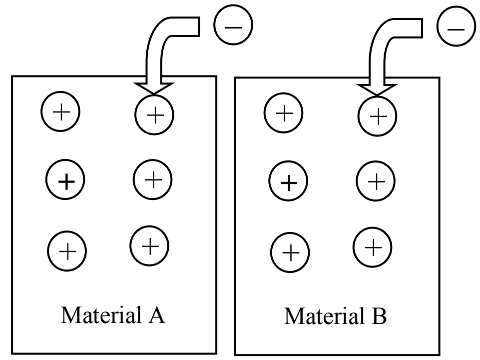


ID	No.	Item
1	1	Wire stripper
2	1 set	Material cards
3	30	Plastic disks with negative signs
4	1	Hand magnifier
5	1	2.5V holiday light bulb with base (not shown)
6	1	Copper foil with self-stick backing
7	2	AA batteries
8	1	Elastic band
9	1	Magnetic board
10	12	Neodymium push pin magnets
11	1	10 linked 2.5V holiday light bulbs with bases
12	1 set	Manila folder with circuits on card stock
13/14	1	Multimeter with probes
15	1	9 V Battery (not shown)

Notebook Circuits with Metering

Activity 1: Electron checkers

Materials:
- Material cards A and B
- Electron circles (20)



Directions:
1. Cover each "+" circle with a "–" circle on "Material A" and "Material B."
2. Remove one of the "–" circles from Material A and place it on Material B.
3. Repeat step 2.
4. *Answer the questions below:*

Questions:
1. Complete the following chart.

Electrons moved from A to B	Charges on Material A +	 -	Charges on Material B +	 -	Net charge on Material A	Net charge on Material B
None moved	10+	10-	10+	10-		
One electron						
Two electrons						

2. If you move a third electron from Material A to Material B, will that electron be repelled or attracted to Material B? What about Material A?

3. Considering your answer to the previous question, do you think it takes energy to move electrons from Material A to Material B? Explain.

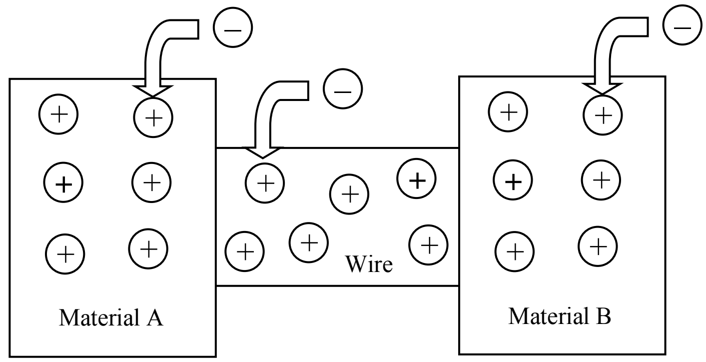
4. Referring to the chart in question 1, which configuration of charges takes the most energy to create, starting from neutral materials?

5. Is there a type of energy that exists based on the locations of charges relative to each other? What is this type of energy called?

6. When a battery is labeled with a "+" and a "-" symbol, what do you think that means?

7. A chemical reaction occurs inside of a battery to move electrons from the positive "+" terminal to the negative "-" terminal. Therefore, what type of energy is used to make electrical energy inside of a battery?

Activity 2: Electrical current



Materials:

- Material cards A and B
- Wire card
- Electron circles (30)

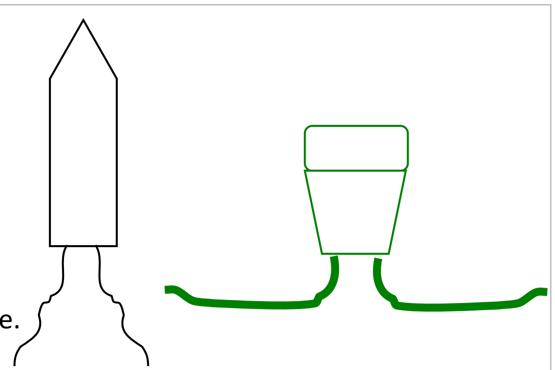
Directions:

1. On a "Wire" card cover each positive ion ("+" circle) with an electron ("–" circle). Also cover each ion on cards A and B.
2. Place Material A so it touches one end of the Wire and Material B so it touches the other end.
3. Remove two electrons from Material A and place them on Material B.
4. The electrons in the wire will be attracted to the excess positive charges in Material A (and repelled by the excess negative charges in Material B). Slide an electron from the end of the wire touching Material A to cover a nearby positive ion on Material A.
5. Move electrons one at a time by sliding them to cover nearby positive ions until there are no more excess charges and every positive ion has an electron.
6. *Answer the questions below:*

Questions:

1. A conducting material contains particles called electrons that can move. These moving electrons create an electrical current. How could you increase an electrical current?
2. When you moved two electrons from Material A to Material B, what effect did this have on the Wire?
3. When the "+" and "-" terminals of a battery are connected to each other by a conducting pathway, why does a current flow?
4. If the conducting pathway between the "+" and "-" terminals of a battery breaks, does a current still flow? Explain why.
5. Which way do electrons move through a wire connected to a battery, from "+" to "-" or from "-" to "+?"

Activity 3: What's inside a bulb?



Materials:

- Hand magnifier
- 2.5 V holiday light bulb w/base

Directions:

1. Use the hand magnifier to view the wiring inside the holiday bulb.
2. Use the hand magnifier to view the wiring inside the holiday bulb base.
3. *Answer the questions below:*

Questions:

1. On the illustration above, draw in the parts of the twinkle light that you observed using the magnifier. Do the same for what you saw inside the bulb base. Label what you see in the base.

2. When the bulb is plugged into the socket, is there a conducting pathway for current to get from one wire of the socket to the other?

3. If you touch the two wires of the bulb to the "+" to "-" terminals of a battery, the bulb will light up. If the bulb "goes out" but the wires are still connected to the battery, what do you think happened to make it go out?

Activity 4: Making a basic circuit

Part 1: Making the battery pack

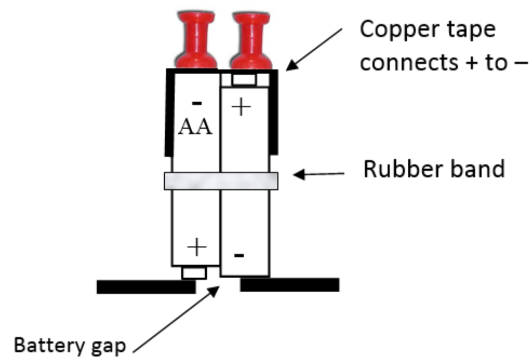


Figure A: 3 V Battery pack

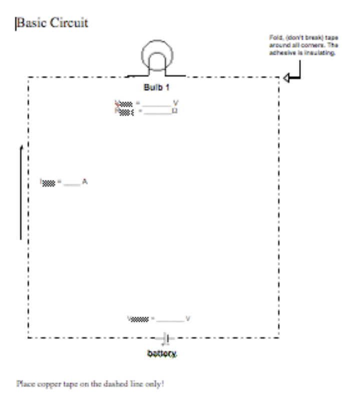
Materials:

- Copper (Cu) foil tape
- AA batteries (2)
- Rubber band
- Neodymium push pin magnets (2)

Directions:

1. Join the two AA batteries together with a rubber band. Orient the batteries as shown in Figure A.
2. To make a copper tape switch for your battery:
   - Cut a 10 cm piece of Cu tape.
   - Remove the paper backing.
   - Fold 4 cm of the tape over onto itself so that you have only 2 cm left with the sticky back.
   - Attach the sticky end to the side of the battery as shown in Figure A.
   - Make sure the switch is long enough to cover both battery terminals.
   - Use two neodymium magnets to keep your battery switch closed as shown in Figure A.

Part 2: Making the basic circuit



Materials:

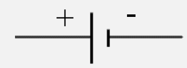
- Copper foil tape
- Basic circuit template on card stock
- 2.5V holiday light bulb (1)
- Magnetic white board
- Neodymium push pin magnets

Directions:

1. Cover the dashed lines of your circuit template with copper tape.
   - **You must fold the tape around the corners to form your circuit. The sticky backing of the tape is an insulator. If you cut the copper tape and tape one piece on top of another you will have an open circuit.**
2. Place your circuit template on your white board.
3. Use two neodymium push pin magnets to attach the light bulb to the circuit.
4. Position the two sides of the battery pack on each end of the battery gap (Figure A).
5. *Answer the questions below:*

Questions:

1. The symbols below are used in circuit drawings to represent wire, bulb and battery, respectively. They are used in your Circuits Data Sheet (attached) and on your notebook circuit boards on cardstock.

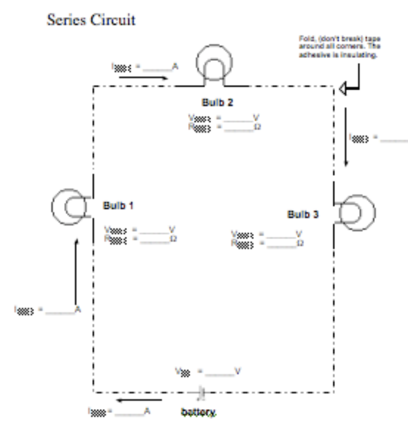
Wire ———————— Bulb  Battery 

2. Refer to the Basic Circuit on your Circuit Data Sheet and draw arrows showing the path the electrons take in the circuit.

3. Energy can be neither created nor destroyed; it can only be transformed from one form to another. Describe two of the energy transformations that occur when you light a bulb with a battery.

4. You hook up a battery to a bulb and it does not light up. In the space below, list at least three different things that may have caused this failure.

Activity 5: Series Circuits



Materials:

- Copper foil tape
- Series circuit template on card stock
- 2.5 V holiday light bulbs (3)
- 3.0 V battery pack (Figure A)
- Magnetic whiteboard
- Neodymium push pin magnets

Directions:

1. Construct the series circuit on the series circuit template.
2. Connect *only one* of the two bare wires on each of three holiday bulbs with the neodymium magnets.
3. Position the 3 V battery pack across the battery gap.
4. Now connect the other wires one at a time and observe the behavior of the holiday bulbs.
5. *Answer the questions below:*

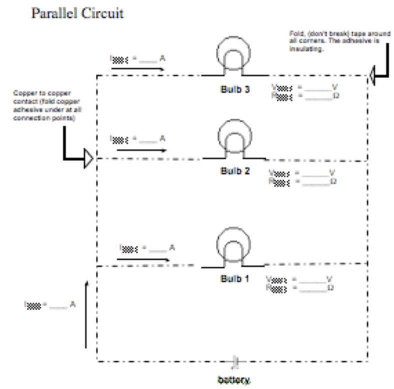
Questions:

1. Refer to the Series Circuit on your Circuit Data Sheet and draw arrows to show the path that the electrons take in the circuit.
2. Complete the following chart based on your experience with your series circuit.

# of bulbs connected	Result
1	
2	
3	

3. Why do you think you got these results? Let's say we rate the brightness of the bulb on your Basic Circuit a "5". What would you rate the brightness of each bulb on your Series Circuit? Write this down on your Data Sheet.

Activity 7: Parallel Circuits



Materials:

- Copper foil tape
- Parallel circuit template on card stock
- 2.5V holiday light bulbs (3)
- 3V battery pack (Figure A)
- Magnetic whiteboard
- Neodymium push pin magnets

Directions:

1. Construct the parallel circuit on the parallel circuit template.
2. Place neodymium magnets where the copper connecting bulbs 2 and 3 intersects the basic circuit.
3. Attach *only one* of the two bare wires on each of three holiday bulbs with the neodymium magnets.
4. With the battery in position, connect the other wires one at a time and observe the behavior of the holiday bulbs.
5. *Answer the questions below:*

Questions:

1. Refer to the Parallel Circuit on your Circuit Data Sheet and draw arrows to show the path the electrons take in the circuit.
2. Complete the following chart based on your experience with your parallel circuit.

# of bulbs connected	Result
1	
2	
3	

4. When the three bulbs were in series all three had to be connected in order for them to light, but this was not the case for the bulbs in parallel. Why?

5. Record the brightness of each bulb on your Circuits Data Sheet.

6. If you were given three light bulbs (resistors), a battery and wire, use symbols to illustrate below one way to connect them that includes both series and parallel circuits.

Activity 8: Metering Notebook Circuits

Materials:

- Notebook circuits on card stock already constructed
- Battery pack (Figure A)
- Digital multimeter
- Magnetic whiteboard
- Neodymium push pin magnets

Directions: Gathering data from your basic, series, and parallel circuits

1. Read the Multimeter Procedure on pages 9-10 before completing steps 2-4.
2. Measure the voltage on your battery pack. Record this value on your Circuits Data Sheet for all of the circuits.
3. For each circuit, measure the voltages and currents at locations shown on the Circuits Data Sheet and record the values under each location.
4. *Answer the questions below:*

Questions:

1. The three bulbs in series were dim, but the three bulbs in parallel were bright. Using the results of your measurements, explain why this is the case. Use your recorded values to determine a relationship between your values recorded with the multimeter and brightness.

2. The voltage of battery is a measure of how much electrical energy is given to each electron. What do you think would happen if you hooked up a 9v battery to a bulb (or your circuits) instead of the 3V battery pack that you used in the lab? Test your prediction.

Metering Procedure

A. Using a multimeter

- A multimeter is a device that can be used to collect data from electrical circuits. A basic multimeter can measure current, voltage, resistance and continuity. In this lab we will only be using the multimeter to measure voltage and current on the direct current (DC) setting (DC current only flows in one direction, i.e.: from a battery). When measuring voltage, we will refer to the multimeter as a voltmeter and, when measuring current, ammeter.

  Units: Voltage: in Volts (V) Current: (mA)

  Note: If you get a reading of 0, make sure you have the digital multimeter set appropriately. If your circuit still doesn't work, then look for the problematic contacts that are causing the open circuit.

B. Measuring the voltage across the light bulbs and the battery: Using the multimeter as a voltmeter.

- Insert black probe in COM, red probe in VΩmA, set meter to 20DCV. (Picture 1a)
- To use the multimeter as a voltmeter (measure voltage) across your battery pack, place the red probe on the positive (+) end of the battery pack and black probe on the negative (-) end of the battery pack (Figure 1b)
- When using the multimeter as a voltmeter (measure voltage) in a circuit, the multimeter needs to be connected to the circuit in parallel. (Figure 1c).
- To measure voltage across a bulb, connect each probe on your copper tape wire on either side of the lighted bulb (Figure 1d).

Picture 1a

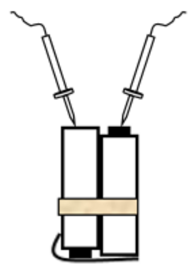


Figure 1b

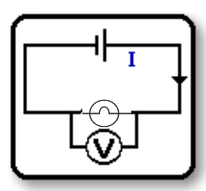


Figure 1c

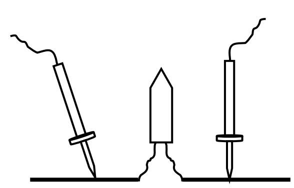


Figure 1d

C. Measuring the current at the light bulbs: Using the multimeter as an ammeter.

- Insert black probe in COM, red in VΩmA, meter set at 200 mA as seen in Picture 2a
- To use the multimeter as an ammeter (measure current), the multimeter needs to be connected in series (Figure 2b)
- To measure the **current that goes through a light bulb,** probe the circuit as shown in Figure 2c.

Picture 2a

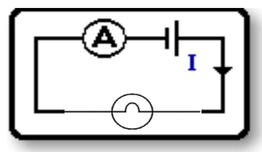


Figure 2b

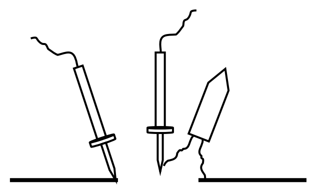


Figure 2c