Period 11 Activity Sheet Solutions: Electric Current

Activity 11.1: How Can Electric Charge Do Work?

Your instructor will demonstrate a Wimshurst machine, which separates electric charge.

a) Describe what happens to the hanging soda cans as electric charge from the Wimshurst machine flows onto the cans. Explain how the separated charge does work on the cans.

The attractive electrical force between the positive charge on one can and the negative charge on the other can causes the two soda cans move closer together over a distance of about 5 cm.

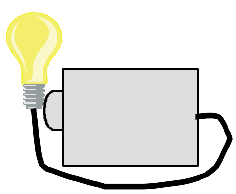
b) Why do you see sparks between the cans or between the balls of the Wimshurst machine?

The attractive electrical force between the cans or between the balls of the Wimshurst machine becomes so great that the separated charge comes back together by moving through the air from one can to the other or from one ball to the other. As the charge moves, some of its electrical energy is converted into thermal, radiant, and sound energy.

Activity 11.2: What is an Electric Circuit?

a) **Lighting a bulb** Arrange one battery, one connecting wire, and one small light bulb (not in a tray), so that the bulb lights. You may need to try several different arrangements.

1) Draw a diagram showing your arrangement of the battery, wire and bulb that worked.



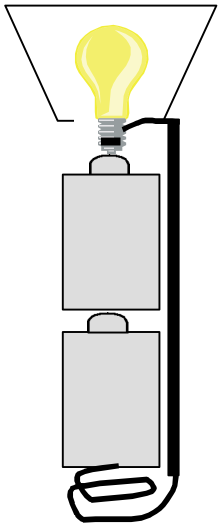
2) Explain why this arrangement worked and other arrangements you tried did not work.

This arrangement makes a complete circuit from the battery through the bulb and back to the battery. The bulb has connecting pathways through the side and bottom of its base. Arrangements that do not connect the side and bottom of the bulb base do not form a closed circuit and will not light the bulb.

b) **Circuit in a flashlight**

In part (a), you found how to light a bulb with a battery and one wire. A flashlight uses the same principle. Examine a flashlight to find the path that the current takes.

1) Draw a diagram of the flashlight showing the path the current follows.



2) If a flashlight does not work, it must have an open circuit. List problems that could cause an open circuit in a flashlight.

An open circuit in a flashlight could be caused by:

- **a burned out bulb (the bulb filament is broken),**
- **the long copper switch not touching metal at its bottom or at its top,**
- **the batteries not touching one another, or**
- **dead batteries, which send no charge through the circuit.**

c) **Plumbing Analogies** Your instructor will demonstrate plumbing analogies for circuits. Fill in the electrical concepts represented by the plumbing display.

1) Water **_electric charge_**
2) Flowing water **_electric current_**
3) Water pressure **_voltage_**
4) Plastic tubes **_connecting wires_**
5) Narrow plastic tubes **_load device_**
6) Pump **_source of separated charge_**

d) Group Discussion Question: Are charges "used up" to make a bulb light? If not, what happens to make it light?

Electric charge is not used up. The same amount of charge that leaves a charge source, such as a battery, flows through the circuit and returns to the source. As electric charge flows through a load device, the energy of the charge is converted into thermal, mechanical, or other forms of energy in the load device.

Activity 11.3: What is Electric Current?

a) **Sources of Separated Electric Charge: Batteries and Capacitors** :

1) Charge a 1 farad (green) capacitor by connecting it to one 1.5 volt battery for about 30 seconds. Connect the charged capacitor to a toy car.

   Describe what happens. Do you think the car would run longer if it were connected to this capacitor or to a D cell battery? Which stores more energy: the capacitor or a battery?
   When powered by the capacitor, the car may run for 5 to 10 seconds. If powered by a battery, the car could run much longer because a battery stores more energy than a capacitor.

2) Charge the capacitor again and connect it to one bulb in a single bulb tray. Approximately how long does the capacitor light the bulb? ____________________

3) How much total charge did you store on the 1-farad capacitor when you charged it with a single 1.5 volt battery?

$$Q = CV = 1 \text{ farad} \times 1.5 \text{ volts} = 1.5 \text{ coulombs}$$

b) **Electric current is a flow of charge**

Connect a 1.5 volt D cell battery and a single-bulb tray with connecting wires so that the bulb lights.

1) Your instructor will show you how to use a **digital multimeter** to measure the amount of current flowing through the circuit. _____________

2) How many coulombs of charge move through this circuit per second?

   Current is measured in units of amperes (amps). Since 1 amp of current = 1 coulomb of charge/second, the number of coulombs of charge per second is the same as the number of amps of current measured in part 1).

3) Suppose that a 1.5 volt battery provides this same amount of separated charge each second for 1 hour. How many 1-farad capacitors would be needed to provide this amount of separated charge? (Hint: you found the amount of separated charge per capacitor in part 11.3.a.3).

   Suppose you measured "Y" number of coulombs of separated charge per second in part 2). Then in 1 hour the battery provides

$$\frac{\text{Y coul}}{\cancel{\text{sec}}} \times \frac{3600\ \cancel{\text{sec}}}{1\ \text{hour}} = \frac{3{,}600\ \text{Y coul}}{\text{hour}}$$

From part 11.3.a.3, each 1-farad capacitor provides 1.5 coulombs of separated charge. Therefore, the number of capacitors needed is

$$\frac{3{,}600\ \text{Y}\ \cancel{\text{coul}}}{\text{hour}} \times \frac{1\ \text{capacitor}}{1.5\ \cancel{\text{coul}}} = \frac{2{,}400\ \text{Y capacitors}}{\text{hour}}$$

c) Group Discussion Question: Since a capacitor stores much less charge than a battery, why are capacitors used?

Activity 11.4: What Voltage Boosts and Drops Occur in a Circuit?

a) **Batteries in series** In this activity, use loose batteries on your table. **Please do NOT take batteries out of the battery trays**!

1) Using a **multimeter**, measure the voltage across one D cell battery. _____________
Measure the voltage across a second D cell. _______________

2) Hold the two batteries together in series as they would be in a flashlight. What is the voltage across BOTH of the batteries? First, think about what might happen, and then measure the voltage.

Prediction: ________________ Measurement:_ **The voltage across the two batteries is the sum of the voltage across each battery** _

3) What will happen to the voltage if you reverse the direction of one of the batteries?

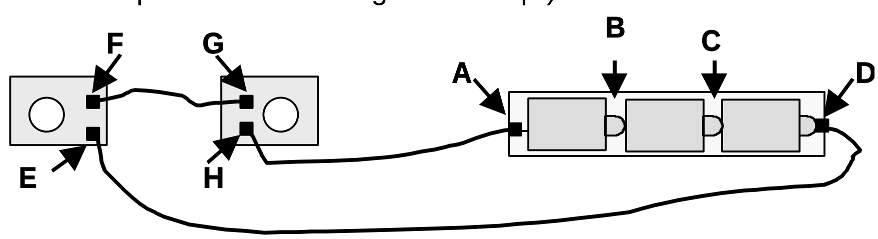
Prediction: ________________ Measurement:__**The voltages of the batteries cancel each other, so the voltage across the two batteries is zero**__

4) Hold four batteries together in series and measure the voltage across them. ____________

5) Reverse the direction of one of the four batteries. Predict and then measure the voltage across the four batteries.

Prediction: ________________ Measurement:__ **The voltages of the two reversed batteries cancel each other.** ___

b) **Voltage boosts and drops in a circuit:** Connect a 3-battery tray and two 1-bulb trays with connecting wires as shown in the diagram. Using a **multimeter**, measure the voltage boosts and drops across the batteries, each of the bulb trays, and the connecting wires. (When measuring the voltage across the connecting wires, place the end of the multimeter lead at the tip of the connecting wire clamp.)



Voltage Boosts		**Voltage Drops**	
Points A to B	______________	Points D to E	_______________
Points B to C	______________	Points E to F	_______________
Points C to D	______________	Points F to G	________________
		Points G to H	________________
		Points H to A	________________

1) What is the total voltage boost across the batteries? ________________

2) What is the total voltage drop across the bulbs and wires? ________________

3) How do the total voltage boosts and total voltage drops in the circuit compare?

The total voltage boosts and total voltage drops are equal.

Activity 11.5: What Is Electrical Resistance?

a) Your instructor will show you how to measure the resistance of electrical appliances. **DO NOT** plug the appliances into an outlet. Record your measurements in the table.

Appliance	Resistance (in ohms)	Appliance	Resistance (in ohms)
Toaster		Hair dryer "high"	
Light bulb		Hair dryer "low"	

1) Which has greater resistance, the hair dryer set at "high" or at "low"? _**low**_

2) Explain why this is so.

When set on "low," the dryer is cooler and requires less electric current to operate. To reduce the amount of current at a given voltage, the load device must have greater resistance.

b) **Resistance and Voltage**

1) Before connecting this circuit, we will measure the resistance of 2 wires that differ only in their length. Using a **multimeter**, measure the resistance of the thin 30 cm nichrome wire (the middle wire on the green board). Write your measurement in the Resistance column of the table. Repeat for the 15 cm nichrome wire. How does the resistance of the 15 cm wire compare to that of the 30 cm wire?

The resistance of the 15 cm wire is approximately one-half the resistance of the 30 cm wire.

2) Your instructor will show you how to connect the nichrome wires together in series with a 3-battery tray. Measure the voltage drop across the 15 cm wire by attaching the multimeter clip leads firmly to the terminals at each end of the wire. Write your measurement in the Voltage Drop column of the table. Repeat for the thin 30 cm wire.

Nichrome Wire Lengths	Resistance (in ohms)	Voltage Drop (in volts)
15 cm		
30 cm		

How does the voltage drop across the 15 cm wire compare to the voltage drop across the thin 30 cm wire?

The voltage drop across the 15 cm wire is approximately one half the voltage drop across the 30 cm wire.

3) Why would a circuit element with greater resistance have a larger voltage drop?

The same amount of current flows through each resistor. It takes more potential energy per charge (voltage) to push the current through the 30 cm wire because it has more resistance to current flow. It takes less electrical energy per charge (voltage) to push the current through the 15 cm wire, which has less resistance.

11.6 How Are Electric Current and Power Related?

a) Your instructor will discuss direct electric current (DC) and alternating electric current (AC). Why can we apply the concepts and equations introduced for direct current circuits to alternating current circuits?

DC current flows in only one direction, while AC current reverses its direction 60 times per second. Since the reversals of direction of AC current occur so rapidly, AC current acts like DC current for purposes of our equations and calculations.

b) Your instructor will show you how to use a **wattmeter** to measure the current, voltage, and power requirements of several AC appliances. Record your data in the table below.

Appliance	Power P (watts)	Voltage V (volts)	Current I (amps)	Calculate $I \times V$
Toaster				
Light bulb				
Hair dryer "high"				
Hair dryer "low"				

c) Do you see a relationship among these three variables? Write an equation that describes the relationship among current, voltage, and power.

The values for current times voltage are approximately equal to the measurement of the power.

$$P = I V$$