Name: _____ Date: _____

INVESTIGATION 13A

Electricity

1 Building a circuit

There are no questions to answer in part 1.

2 Thinking about what you observed

a. How can you tell electric current is flowing in the circuit? Can you see the current flow?

b. Current flows from positive to negative. Trace the flow of current around the circuit with your finger.

c. How does the switch cause the current to stop flowing?

d. Why does the bulb go out when you open the switch?

e. Draw an energy flow diagram of the circuit. Label the forms of energy that appear.

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INVESTIGATION 13A

3 Conductors and insulators

There are no questions to answer in part 3.

4 Thinking about what you observed

a. Make a table listing the materials as either conductors or insulators.

Conductors	Insulators

b. What characteristics are shared by the conductors you found?

c. What characteristics are shared by the insulators you found?

5 Measuring the voltage of a battery

There are no questions to answer in part 5.

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INVESTIGATION 13A

6 Measuring current

a. How much current is flowing in the circuit when the bulb is making light?

_____

7 Circuit diagrams

a. Using these symbols, draw a picture of the circuit you built with one battery, switch, and light bulb.

8 A circuit with a dimmer switch

Table 1: Pot settings and voltage across bulb

Pot dial position	Voltage across bulb (V)	Observed light output of bulb

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9 Thinking about what you observed

a. As you changed the settings of the pot, what happened to the voltage across the bulb?

b. Did you observe a relationship between the voltage across the bulb and the light output?

c. Propose a relationship between power and voltage that would explain the light output of the bulb.

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INVESTIGATION 13B

Resistance and Ohm's Law

1 Measuring resistance

Table 1: Resistance Measurements

Object description	Conductor or Insulator	Resistance (Ω)

2 The meaning of resistance

a. What relationship did you notice between the resistance and whether a material was a conductor or insulator?

b. Describe the ability of an object to conduct electrical current in terms of its resistance.

c. Write down Ohm's law and describe what each of the three symbols stands for (including units).

d. Two simple circuits are built with two different electrical devices. Each contains the same size battery. One device has a resistance of 100 ohms (100 Ω) and the other has a resistance of 1,000 ohms (1,000 Ω or 1 kΩ). Which circuit has more current? Use the concept of resistance to explain why.

3 Mystery resistors

Table 2: Resistor Currents

Resistor color	Battery voltage (V)	Current (amps)

a. Use your knowledge of Ohm's law to determine which resistor is which. The resistance you calculate from Ohm's law will not come out exactly to 5, 10, or 20 because the meter itself has a small resistance.

4 Resistance and potentiometers (pots)

Table 3: Pot settings and resistance

Pot dial position	Resistance (Ω)

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INVESTIGATION 13B

5 The bulb dimmer circuit

a. Use the concept of resistance to explain how the pot controls the brightness of a bulb.

b. Suppose the resistance of the bulb is 5Ω. The total resistance of the circuit is 5Ω plus the resistance of the pot. Use Ohm's law to calculate the maximum and minimum current flowing through the circuit when the pot is turned fully on or off. Assume a voltage of 1.5 V is applied by the battery.

6 The voltage drop

Table 4: Pot settings and voltage drops

Pot dial position	Voltage drop across pot (V)	Voltage drop across bulb (V)	Observed light output

a. What relationship do you observe between the voltage drop across the pot and the voltage drop across the bulb?

b. What does the voltage drop tell you about the electrical energy carried by the current?

c. What relationship do you observe between the measured voltage drops and the battery voltage?

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INVESTIGATION 14A

Electric Circuits

1 Series circuits

Table 1: Voltage measurements (volts)

Between A and B	Between B and C	Between C and D	Between A and D

2 Thinking about what you measured

a. What relationships do you see among the voltage measurements in Table 1?

b. What do the voltage measurements tell you about the flow of energy in the circuit?

3 The current in series circuit

Table 2: Current Measurements (amps)

Three bulbs	Two bulbs	One bulb

4 Thinking about what you observed

a. What happens to the current in the circuit as the number of bulbs is reduced? Explain why this occurs using Ohm's law and the concept of resistance.

b. What happens to the other two bulbs when one bulb is removed from the three-bulb circuit? Try it and explain why the circuit behaves as it does.

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INVESTIGATION 14A

5 Short circuits

There are no questions to answer in part 5.

6 Thinking about what you observed

Table 3: Short Circuit Current Measurements (amps)

Three bulbs in series	Three bulbs with two short circuited

a. Compare the current in the three-bulb circuit with the current when two bulbs are bypassed by a short circuit. Which is greater? Use Ohm's law and the concept of resistance to explain why.

b. How does the current in the "short circuit" version compare with the current you measured in a one-bulb circuit? Explain why this should be true.

c. How does the resistance of a wire compare to the resistance of a bulb? Measure the resistances to test your answer. NOTE: Most meters cannot measure very low resistance and display "0.00" when the resistance is lower than 0.01 Ω.

d. Why would a short circuit be dangerous? Discuss (as a class) the consequences of very large currents in wires of different sizes.

7 Parallel circuits

Table 4: Voltage and current in a parallel circuit

	Total circuit	Bulb 1	Bulb 2	Bulb 3
Voltage (*V*)				
Current (*A*)				

8 Thinking about what you observed

a. Compare the brightness of the bulbs in the parallel circuit with the brightness in the series circuit.

b. Compare the total current in the single-bulb circuit, the three-bulb series circuit, and the three-bulb parallel circuit. Propose a relationship between the currents that agrees with the brightness of the bulbs.

c. Remove one bulb from the circuit by unscrewing it from its socket. Observe what happens to the remaining bulbs.

d. Did the other two bulbs continue to light when the third bulb was removed from the parallel circuit? Explain why. How does this differ from what happened with the series circuit?

e. Do you think the electrical outlets in your home are connected in a series or parallel circuit? Give two reasons why one type of circuit has an advantage over the other for connecting outlets.

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INVESTIGATION 14B

Electrical Energy and Power

1 Energy and power in an electrical system

Table 1: Power used by a bulb

Voltage (V)	Current (A)	Power (W)

2 Thinking about what you observed

a. How did the power used by the bulb compare at the two different voltages?

b. Was the bulb brighter, dimmer, or about the same at 3 V compared to 1.5 V? Explain any difference you observed using the concept of power.

3 Energy and power from a battery

There are no questions to answer in part 3.

4 Thinking about what you observed

a. How was energy flowing when the capacitor was "charging up"? What was the source of the energy and where did it go?

b. How was energy flowing when the bulb was connected and the battery was removed? What was the source of the energy and where did it go?

c. Why did the bulb go out after a few seconds. Explain what you observed in terms of the ideas of energy and power.

5 Energy and power

Table 2: Energy and power data at 1.5 V

Starting voltage (V)	Number of bulbs	Time until bulb goes out (sec.)			Average of 3 trials (sec.)

6 Thinking about what you observed

a. What is the total power used by 1, 2, and 3 bulbs connected in parallel? In a parallel circuit each device draws current as if it were the only device in the circuit.

b. What relationship do you observe between the time the bulbs stay lit and the total power used?

c. Since power is energy ÷ time, the formula can be rearranged to give energy = power × time. For example, if you use 10 watts for 10 seconds, you have used a total of 100 joules of energy (100 J = 10 W × 10 sec.). Use your data to estimate how many joules of energy are stored in the capacitor at 1.5 V.

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INVESTIGATION 15A

Electric Charge

1 Observing electric charge

There are no questions to answer in part 1.

2 Thinking about what you observed

a. Describe what happens to the aluminum foil leaf as you move the balloon closer.

b. Explain the reaction of the leaf to the rubbed balloon using the concepts of positive and negative charge.

c. Explain why touching the balloon to a metal object changed its effect on the leaf.

3 Making an electroscope

There are no questions to answer in part 3.

4 Thinking about what you observed

a. Describe what happens to the aluminum foil leaves as you move the rubbed balloon closer.

b. Give a reason why the leaves stay apart after the balloon is removed.

c. Explain what happens when you touch the wire with your hand or a metal object.

d. "Charge" the electroscope by touching it with a balloon that has been rubbed against your hair. Then touch the rubbed side of the balloon to something metal and bring it close to the electroscope again. Describe what happens.

e. Why does the plastic rod cause the leaves to move only after it has been rubbed with the fleece?

f. What causes the leaves of the electroscope to move apart?

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INVESTIGATION 15B

The Flow of Electric Charge

1 Current and charge

Table 1: Capacitor discharge data

Time (sec)	Voltage (V)	Time (sec)	Voltage (V)
0		30	
10		40	
20		50	

2 How much current flowed?

a. Use Ohm's law to write down a formula for the current flowing through an electrical device if you know the voltage drop and the resistance.

_____

_____

b. Use the relationship you found in 2a (above) to fill in Table 2 by calculating how much current was flowing through the resistor.

Table 2: Capacitor current data

Time (sec)	Current (A)	Time (sec)	Current (A)
0		30	
10		40	
20		50	

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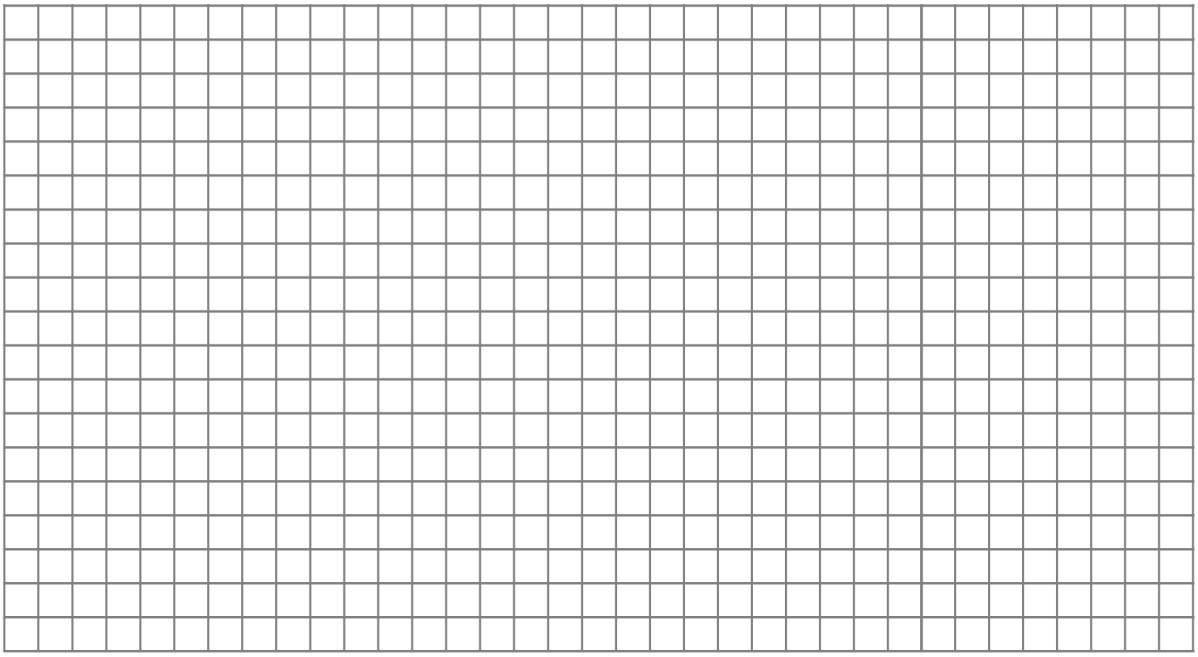
INVESTIGATION 15B

3 Thinking about what you observed

a. Make a graph of the current versus time for the capacitor. Break the graph up into vertical bars that are ten seconds wide. (See example graph below)

Title: _____

y label: _____



x label: _____

b. Set the height of each bar to the average value of the current over each ten second time interval. You can do this by eye since that will be good enough for the accuracy of the experiment.

c. Write down a formula that allows you to calculate the charge if you know the current and the time.

_____

_____

d. Calculate how much charge flowed in each ten second interval by multiplying the average current by ten seconds (Table 3).

_____

_____

e. Add up the charge from each interval to get the total charge. This is the amount of charge that was in the capacitor when it was "full."

Table 3: Calculating the charge

Average current (A)		Time Interval		Charge (C)
	X	10 sec	=	
	X	10 sec	=	
	X	10 sec	=	
	X	10 sec	=	
	X	10 sec	=	
	X	10 sec	=	
			Total for 60 seconds	

4 Estimating the number of electrons that move

a. Look up the charge of a single electron in coulombs (C).

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a. Calculate how many electrons are in the total charge from Table 3.

---

a. Measure the mass of the capacitor in kilograms.

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a. Estimate how many electrons are in the capacitor. You can do this calculation in the following steps.
(1) Write down the mass of a proton (1 amu) in kg.
(2) Calculate how many protons there are by assuming $^1/_2$ the mass of the capacitor is protons.
(3) The number of electrons is the same as the number of protons.

b. Calculate the number of electrons that move by dividing the result of step b by the number you found in step d.

5 Thinking about what you observed

a. Was the number of electrons that moved larger, smaller, or about the same as the number of electrons in the capacitor? Was the difference very large or very small?

b. Why were we able to estimate the number of protons as $^1/_2$ the total mass even though we did not know what elements the capacitor was made of?

c. Is the estimate of the number of electrons larger or smaller than the true number? Do you think the difference is larger or smaller than 25%? Give a reason for your answer.