Name:

19.1 Electric Circuits

Question: What is an electric circuit?

1 Building circuits with a battery, a bulb, and a wire

a. Using *only* one battery, one bulb, and one wire, find four different ways you can arrange these three parts to make the bulb light. As you work, determine the kinds of connections that are needed to make the circuit work.

b. Record all your circuit attempts. Draw both successful and unsuccessful attempts.The drawing at right shows a simple way to draw the bulb, battery, and wire.

c. Make sure your drawings show the difference between the two ends of the battery. Also show exactly where the bulb is touching the wire and the battery.

d. Explain why you think some configurations work and others do not. Record your first thoughts and impressions—and don't worry if they are right or wrong.

2 Using the electric circuits set

There are no questions to answer in Part 2.

3 Drawing circuit diagrams

There are no questions to answer in Part 3.

4 Observing how a switch works

a. Examine the switch as it turns the bulb on and off. Explain how the switch works. You may use both words and drawings.

5 What did you learn?

a. Water can travel through air but cannot travel through a solid. Using what you learned in this Investigation, describe some materials that electricity can and cannot travel through.

b. The word *circuit* comes from the same root as the word "circle." Describe the similarities between a circle and the circuits that you built.

c. A circuit that is on and working is sometimes called a *closed circuit*. Based on your observations of the switch, explain what *closed* means in a circuit.

d. A circuit that is off or that is not working is sometimes called an *open circuit.* Based on your observations of the switch, explain what *open* means in a circuit.

Name:

19.2 Current and Voltage

Question: How does current move through a circuit?

1 Building test circuit #1

There are no questions to answer in Part 1.

2 Measuring current through test circuit #1

Follow the procedures and record your readings below:

3 Test circuit #2

Follow the procedures and record your readings below:

4 What did you learn about current?

a. Review the two current readings for circuit 1. What conclusions can you draw from these results?

b. Review the three current readings for circuit 2. What conclusions can you draw from these results?

c. Transfer all your results for circuit 1 and circuit 2 into the table below. Compare the current readings in the two circuits. What happened to current when you added a bulb to the circuit?

	Current in circuit 1 (amps)		Current in circuit 2 (amps)
Point A	.092	Point A	.070
Point B	.091	Point B	.070
		Point C	.068

d. In which circuit were the light bulbs brighter? Offer a possible explanation for this.

5 Measuring voltage across a battery

Follow the procedures and record your readings below:

6 Measuring voltage across a battery and bulb in a circuit

Follow the procedures and record your readings below:

7 What did you learn about voltage?

a. Were your predictions correct?

b. Was there much difference in the battery voltage when it was not lighting the bulb and when it was?

c. How did the battery's voltage compare with the bulb's voltage? Why do you think this is?

8 Building circuits with two batteries

a. Describe how you should wire batteries together to light the bulb.

b. Each battery is 1.5 volts. Explain how to calculate voltage when two batteries are connected.

c. Compare the brightness of a bulb in a one-battery circuit to that of a bulb in a two-battery circuit. How is the bulb's brightness related to energy transfer in each circuit?

d. Explain the meaning of the voltage reading across the bulb.

Extra space for notes and performing calculations:

Name:

19.3 Electrical Resistance and Ohm's Law

Question: How are voltage, current, and resistance related?

1 Resistance and current

a Explain why the current changes when the dial of the potentiometer is turned. The dial controls the resistance of the potentiometer, which varies from 0Ω (ohms) to 105Ω.

b. Explain why the bulb is dim or bright depending on the position of the potentiometer. Your answer should use the concepts of resistance, energy and current.

2 The current and voltage relationship for a fixed resistor

Table 1: Voltage vs. current

Potentiometer setting	Current (A)	Voltage (V)

3 Finding the relationship between voltage, current, and resistance

a. Examine the data in Table 1. Describe in words what happens to the voltage across the fixed resistor as the current decreases.

____

____

____

b. Graph the data from Table 1. Put voltage on the *y*-axis and current on the *x*-axis. Label your *x*- and *y*-axes and title your graph.

Title: ______________________________

y label: ______________________________

x label: ______________________________

c. Draw a best-fit line that matches the trend of the points on your graph. Calculate the slope of the line.

____

d. The resistance of the green fixed resistor is 5 ohms. How does this value compare with the slope of your graph?

____

e. The equation that relates current, voltage, and resistance is called Ohm's law. Write the mathematical equation for Ohm's law using *V* for voltage, *I* for current, and *R* for resistance.

____

4 Voltage and current for a light bulb

Table 2: Voltage vs. current for a bulb

Potentiometer setting	Current (amps)	Voltage (volts)

5 Analyzing the bulb's current, voltage, and resistance

a. What happened to the brightness of the bulb as you deacreased the current?

____

b. Graph the data from Table 2. Put voltage on the *y*-axis and current on the *x*-axis. Label your *x*- and *y*-axes and title your graph.

Title: ____

y label: ______________________

x label: ______________________

c. Compare the shape of the graph for the light bulb to the shape of the graph for the fixed resistor.

d. Use Ohm's law to calculate the resistance of the light bulb for each pair of voltage and current values.

e. How is the resistance of the light bulb related to the amount of current through it?

f. Discuss a possible reason for the bulb's resistance changing.

Name:

20.1 Series and Parallel Circuits

Question: How do series and parallel circuits work?

1 Voltage and current in series circuits

Table 1: Comparing series circuits

	1-bulb circuit	2-bulb circuit	3-bulb circuit
Battery voltage (V)			
Current (A)			
Bulb 1 voltage (V)			
Bulb 2 voltage (V)			
Bulb 3 voltage (V)			

2 Thinking about what you observed

a. Use the data in Table 1 to explain the relationship between the battery voltage in a circuit and the voltage across the bulb or bulbs connected in series.

b. What did you notice about the brightness of the bulbs as you increased number of bulbs in the circuit? Why do you think this is? How do the measurements you made support your hypothesis about why the bulbs changed in brightness?

c. What happens to the other two bulbs when one bulb is removed from the three-bulb circuit? Explain why the circuit behaves as it does.

3 Determining the total resistance of resistors in series

a You will use two 5-ohm and one 10-ohm resistor during this Investigation. Predict what the total resistance of the circuit will be when all three resistors are connected in series.

b. Predict the circuit's total current when 3 volts are applied using two batteries.

4 Measuring the current and resistance in series circuits

Table 2: Three-resistor series circuit measurements

Current (amps)	Voltage (V)	Resistance (ohms)

a Use Ohm's law (in the form $R = V/I$) to calculate the total resistance in each circuit from the combined battery voltage (Table 1) and the current for each circuit (Table 2). Record your results in the bottom row of Table 2.

b. Compare your measurements with the predictions of Part 3. Explain the effect that adding resistors has on the current flowing in a series circuit.

5 Parallel circuits

Table 3: Comparing series circuits

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

6 Comparing series and parallel circuits

a. Use Ohm's law and the total circuit voltage and total circuit current from Table 3 to calculate the total resistance of the circuit with three bulbs in parallel. Record the result in the last row of Table 3.

b. Use Table 4 to summarize the total circuit current and voltage measurements from the single-bulb circuit and the two different three-bulb circuits (series and parallel).

Table 4: Comparing series and parallel circuits

	Single-bulb circuit	3-bulb series circuit	3-bulb parallel circuit
Current (A)			
Voltage (V)			
Resistance (Ω)			

c. Compare the total resistance of the single-bulb circuit with the total resistance of the three-bulb series circuit. Which circuit resistance is greater? Why do you think this is?

d. Compare the total resistance of the single-bulb circuit to the total resistance of the three-bulb parallel circuit. Which circuit resistance is greater? Why do you think this is?

e. How are the branch currents in the parallel circuit related to the total current supplied by the batteries? Explain how you arrived at your answer.

f. Compare the total current in the single-bulb circuit, the three-bulb series circuit, and the three-bulb parallel circuit. Is there an approximate relationship between the currents that also agrees with the observed brightness of the bulbs in each circuit?

g. If you wish to brightly light three bulbs with one battery, should you connect them in series or parallel?

h. Calculate the total current that should flow when three resistors (of 5, 5, and 10 ohms) are connected in parallel as shown. Build and test the circuit to evaluate your prediction. How close was your prediction to the actual measurements?

Name:

20.2 Analysis of Circuits

Question: How do you analyze network circuits?

1 Determining the resistance of each resistor

Table 1: Measured resistance values

	R1	R2	R3	R4
Resistance (Ω)				

2 Building a network circuit

Record the data in the table.

3 Analyzing the circuit

Table 2: Voltage and current measurements

	Battery (total circuit)	R1	R2	R3
Voltage (volts)				
Current (amps)				

a. Which of the two resistors is connected in parallel? _________________

b. Which resistor is in series with the other two? _________________

c. How does the voltage across the parallel resistors (R_2 and R_3) compare?

d. How does the voltage across the parallel resistors relate to what you learned about voltages in a parallel circuit in the previous Investigation?

e. Voltage is the measure of the amount of energy carried by the current in a circuit. Trace the path of the current from the positive end of the battery, through the circuit, to the negative end of the battery. There are two possible paths because of the parallel part of the circuit but each path will only pass through two of the resistors. Does the amount of energy lost through the resistors equal the amount of energy supplied by the battery? Is this the case for each possible path? Explain.

f. How does the current flowing through R_1 compare with the current through R_2?

g. How does the current coming out of the battery compare with the sum of the currents flowing through R_2 and R_3? Explain this relationship.

h. Use what you know about series and parallel circuits to calculate the theoretical total resistance of the circuit.

i. Now calculate the total resistance of the circuit using Ohm's law, the battery voltage, and the total circuit current you measured.

j. How does the total resistance calculated using Ohm's law compare with the theoretical total resistance found above?

4 Predicting the effect of changing a resistor

a. Replace the10-ohm resistor (R_3) with the 20-ohm resistor (R_4). Use what you have learned about network circuits to predict the total circuit resistance and total circuit current. Show the process you used to make your predictions.

b. Measure the voltage across the battery and each resistor and the total current in the circuit. Use Ohm's law to find the total circuit resistance. You will need to make a data table similar to Table 2.

c. How did the predicted values compare with the measured ones?

5 A circuit puzzle

a. When bulb B is disconnected, does bulb A get dimmer, brighter, or stay the same?

b. When bulb B is disconnected, does bulb C get dimmer, brighter, or stay the same?

c. Use what you know about series and parallel circuits to propose an explanation for what you observed.

6 Challenge: Analyze a four-resistor network circuit

a. Build the circuit shown in the diagram at right.

b. Use what you have learned about network circuits to predict the total circuit resistance and current. Show the process you used to make your predictions.

c. Use the meter to measure the voltage across the battery and each resistor and the total circuit current. Use Ohm's law to find the total circuit resistance.

d. How did the predicted values compare with the measured ones?

Extra space for notes and performing calculations:

Name:

20.3 Electric Power, AC, and DC Electricity

Question: How much does electricity cost?

1 Find the power rating of home appliances

a. Fill out the first two columns of Table 1 as you find the power rating of each appliance. The second column should be in kilowatts.

b. Convert any power ratings listed in watts to kilowatts. To convert to kilowatts, divide the number of watts by 1,000. For example, 1,500 watts is equal to 1,500 ÷1,000, or 1.5 kilowatts.

c. Estimate the number of hours the device is used each month. Assume that one month equals 30 days. If your coffee maker is used for a half hour each morning, you would calculate a monthly usage of 15 hours (0.5 hr/day × 30 days).

Table 1: Power rating, usage, and cost of household appliances

Appliance	Power rating in kW	Est. usage hrs. per mo.	No. kWh per mo.	Price per kWh	Total cost per mo.

2 Estimate the number of kilowatt-hours each appliance uses in a month

a. Multiply the power rating in kilowatts (from the second column) by the number of hours the appliance is used each month. For example, if you use a 1-kilowatt toaster for five hours a month, multiply 1 times 5. Write your answers in column 4 of Table 1 as shown in the sample below:

Appliance	Power rating in kW	Est. usage hrs. per mo.	No. kWh per mo.	Price per kWh	Total cost per mo.
Microwave	1.4 kW	22 hours	30.8		

3 Determine the monthly cost of using your appliances

a. Find out how much you pay per kilowatt-hour. In some areas, one utility company provides all the electricity to an entire region while in other places several companies compete for customers.

b. Write the price per kilowatt-hour in column 5 of Table 1.

c. Calculate the amount of money your household spends to operate each appliance during one month. Multiply the kilowatt-hours per month by the price per kilowatt-hour to determine your cost.

4 Analyze your data

a. Compare your results with those of the other members of your group. List the three appliances from your group that had the highest power ratings in Table 2.

b. Think about the function of each appliance listed in Table 2. What kind of work is being done? In other words, electrical energy is converted into what other type(s) of energy?

c. Do you see any similarities in the kinds of work being done by the three appliances in Table 2? If so, what are these similarities?

d. Suggest one practical way you or another group member could reduce your electricity bills.

e. Discuss the effect of climate on electricity use. What climate factors might influence which month has the peak electricity use in your area?

f. Name one other factor (not related to climate) that may influence which month has the highest electricity use in your area.

Table 2: Appliances with the highest power ratings

Appliance	Power rating in kilowatts

5 What do you buy from the electric utility company?

a. Which units in the last equation cancel?

b. After canceling the units that appear in both the numerator and denominator, what fundamental unit remains?

c. Is the remaining unit a measure of energy, work, or power?

d. Do electric companies sell energy, work, or power?

Extra space for notes and performing calculations:

Name:

21.1 Electric Charge

Question: How do electric charges interact?

1 Building a simple electroscope

There are no questions to answer in Part 1.

2 Creating static charges: Part I

There are no questions to answer in Part 2.

3 Observing the interaction between the tapes: Part I

Follow the procedures and record your observations below:

4 Creating static charges: Part II

There are no questions to answer in Part 4.

5 Observing the interaction between the tapes: Part II

Follow the procedures and record your readings below:

6 What did you learn?

a. How many types of interactions did you observe between the pieces of tape?

b. The first tapes you prepared pushed each other away, or *repelled,* each other. These two pieces of tape have the same kind of charge. This makes sense since you prepared the tapes in the same way. On the other hand, the A tape has one kind of charge and the B tape has a different kind of charge. Are the first tapes you prepared both A tapes or both B tapes? Explain how you figured this out.

c. Give your hypothesis for how the A and B tapes might have acquired different kinds of charge.

7 Extension: Using the electroscope to detect other charged objects

In sixteenth-century England, William Gilbert, the queen's physician, built the first electroscope. He noticed that the electroscope attracted lightweight objects. See if you can reproduce his results.

1. Remove the tape from your electroscope.
2. Prepare and label a fresh set of A and B tapes and place them on two arms anchored in one piece of clay.
3. Take light objects such as thread, small pieces of paper, and hair and slowly bring them close to both the A and B tapes.
4. Record your observations.

Name:

21.2 Coulomb's Law

Question: How strong are electrical forces?

1 Electrical forces in a penny

a. A single proton or electron has a charge of 1.602×10^{-19} coulombs. How many coulombs of protons and electrons are in each penny?

b. Imagine you have two pennies, A and B. You remove all of the electrons from penny A and place them on penny B. Is penny A positively or negatively charged? Is penny B positively or negatively charged?

c. Calculate the force of attraction between the two pennies if they are held 1 meter apart.

d. A diesel locomotive weighs approximately 1,000,000 newtons. Determine the number of locomotives necessary to have a weight equal to the strength of the force between the pennies.

e. You were probably surprised when you calculated the force between the pennies. What does your answer tell you about the amounts of charge normally transferred in activities such as brushing your socks on carpet or rubbing a balloon on your hair?

2 Charged balloons

Table 1: Balloon charging data

Mass of balloon A (kg)	Trial	Distance (m)
	1	
	2	

3 Analyzing the data

a. How did the distance in trials 1 and 2 compare? Why do you think this is?

b. When the interaction between the balloons causes the string to become slack (tension is zero), what two forces on balloon A must be equal?

c. Calculate the weight of balloon A.

d. Use Coulomb's law to calculate the charge on each balloon (in coulombs) for each trial. You can assume each balloon is charged the same amount.

e. Calculate the number of excess electrons on the balloons in each trial.

Name:

21.3 Capacitors

Question: How does a capacitor work?

1 Current and voltage for a capacitor

There are no questions to answer in Part 1.

2 Setting up the experiment

a. Describe the flow of current when switch 1 is closed and switch 2 is open. This is the *charging* circuit for the capacitor.

____

____

b. Describe the flow of current when switch 2 is closed and switch 1 is open. This is the *discharging* circuit for the capacitor.

____

____

3 Charging and discharging the capacitor

Enter your data into Tables 1 and 2 below.

Table 1: Charging Data

Time (sec)	Voltage (V)

Table 2: Discharging Data

Time (sec)	Voltage (V)

a. Use Tables 1 and 2 to make a graph of voltage versus time for charging and discharging the capacitor.

Title: ______________________________

y label: ______________________________

x label: ______________________________

b. Describe the shape of the graphs. Are they linear?

____

____

c. If you were to continue charging the capacitor for a long time, would the voltage reach a maximum value or continue to climb steadily? Your graph should help you answer this question.

____

____

d. Suppose you wanted to charge your capacitor to the full battery voltage. Would this take twice as long as the time to reach half the battery voltage? Why or why not?

____

____

e. Imagine you had measured the current in the circuit while charging or discharging the capacitor. Would the current have been constant or would it have changed over time? Sketch the shape of the current versus time graphs you think you would have measured during charging and discharging.

f. (Challenging) Both a capacitor and a battery can create voltage differences and drive electric current. Give at least three electrical differences between a capacitor and a battery.

4 The effect of changing the charging or discharging current

Table 3: Capacitor charging times

Resistance (Ω)	Time to reach 1.5 V (sec)

a. Describe the effect of changing the resistor in the circuit.

b. How does the current compare for the three different resistors?

c. Explain why the time it took the capacitor to reach 1.5 volts was different for each of the three resistors. Use your knowledge of current, resistance, and capacitors.

Name:

22.1 Properties of Magnets

Question: How do magnets interact with each other?

1 Describing the forces that two magnets exert on each other

a. Write down a rule that describes how magnets exert forces on each other. Your rule should take into account your observations from steps 1 through 3.

2 Determining how far the magnetic force reaches

a. When referring to many measurements of the same quantity, *precision* describes how close the measurements are to each other. Estimate the precision (in millimeters) of your measured magnet interaction distance using the largest difference between any one measurement and the average.

b. Look at your results and compare the average distances for the three combinations of poles. Are the attract and repel distances *significantly* different? In science, "significantly" means the differences are large compared to the precision of your measurement.

Table 1: Magnetic forces between two magnets

	North-South	South-South	North-North
Distance 1 (mm)			
Distance 2 (mm)			
Distance 3 (mm)			
Average distance (mm)			

3 Magnetic field lines

There are no questions to answer in Part 3.

4 Interpreting the diagram

a. The pattern you drew shows the shape of the magnetic field around the stack of magnets. Connecting the small arrows together forms magnetic field lines. Describe the shape of the magnetic field around the stack of magnets.

b. Do the magnetic field lines point toward or away from the north pole of the stack of magnets?

c. You learned about *electric* field lines when studying positive and negative charges. How are magnetic field lines similar to electric field lines? How are they different?

d. Which of the following has electric field lines shaped similar to the magnetic field lines for a bar magnet?

- One positive charge.
- One negative charge.
- A pair of positive charges.
- A pair of negative charges.
- A positive charge next to a negative charge.

Name:

22.2 Magnetic Properties of Materials

Question: How do magnets interact with different materials?

1 Testing materials to see if they are affected by magnets

Table 1: How different objects are affected by magnets

Object	Material composition	Attract	Repel	No effect

a. The word *magnetic* is used to describe things that are affected strongly by magnets. What common property do you see in the materials you observed to be magnetic?

b. Do the terms *repulsive* and *nonmagnetic* mean the same thing?

2 Ferromagnetism

There are no questions to answer in Part 2.

3 Do nonmagnetic materials affect the magnetic force?

Table 2: Testing nonmagnetic materials

	No material between magnets	material: ________	material: ________	material: ________
Distance 1 (mm)				
Distance 2 (mm)				
Distance 3 (mm)				
Average (mm)				

a. Examine your results in Table 2. Does the strength of the magnetic force diminish by passing through any of the materials you tested?

Name:

22.3 The Magnetic Field of the Earth

Question: How do we use Earth's magnetic field to tell direction?

1 Why a compass works

a. If the magnetic north pole of a compass needle points toward Earth's geographic north pole, what is the orientation of Earth's magnetic field? Is the geographic north pole of the planet a magnetic north or a magnetic south pole?

b. The north pole of a compass needle always points toward which pole of a permanent magnet?

2 Reading a compass

There are no questions to answer in Part 2.

3 Declination

a. Research the magnetic declination for your area.

b. If the magnetic declination were zero, straight east would be a bearing of 90 degrees on a compass. What compass bearing will you set if you wish to go straight east but need to correct for the local magnetic declination?

4 The effect of magnetic materials on a compass

There are no questions to answer in Part 4.

5 Reflecting on your observations

a. How close did the magnet have to be before it affected the compass? There are magnets in many devices such as television sets, electric motors, and computers. How far away from these devices must you be before you can trust the reading from a compass?

b. The bodies of automobiles are made of magnetic steel yet you can buy a compass for your car. Some cars even have electronic compasses built in. Based on your observations, would you believe the directions from a compass inside a car?

c. A compass does not work close to Earth's geographic north or south poles. Draw a sketch showing the Earth's magnetic field and use the drawing to explain why compasses have this limitation.

Name: ______________________________

23.1 Electric Current and Magnetism

Question: Can electric current create a magnet?

1 Build an electromagnet

1. Wrap a nail tightly with wire as shown at right. Leave 30 centimeters of uncoiled wire on each end of the nail. Count the number of turns you wrap and write the result here.

   Turns: ___________________

2 Compare electromagnets and permanent magnets

a. The electromagnet certainly does not look much like the permanent magnets you are familiar with. Using what you know about magnets, think of at least two tests to show that your electromagnet acts like a permanent magnet. Describe your two proposed tests.

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b. Connect your electromagnet to the battery and perform the two tests you described in the previous step of the Investigation. Record your observations.

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____

c. Does the electromagnet act like a permanent magnet? Explain.

3 The right-hand rule

a. Use a permanent magnet or compass to determine the location of the north and south poles of your electromagnet. Explain your method and include a diagram showing the direction of the current from the positive battery terminal, around the nail, and into the negative battery terminal.

b. Reverse the direction of the current through your electromagnet by switching the locations where the electromagnet wires' ends connect to the battery. Test for the locations of the north and south poles. What effect did reversing the current have on the locations of the poles?

c. The polarity of an electromagnet can be predicted easily if you know the direction of the current in the coil. When the fingers of your right hand curl in the direction of the current, your thumb points toward the electromagnet's north pole. This method of finding the magnetic poles is called the *right-hand rule*. Use the right-hand rule to find the locations of the poles of your electromagnet.

4 What happens to the strength of an electromagnet when you increase the current?

Table 1: Current and magnet strength

Turns	No. of batteries	Current (A)	No. of paper clips picked up

5 What did you learn?

a. Draw a graph showing how the number of paper clips picked up by the magnet varies as the current increases. Label your axes and title your graph.

Title: ____________________

y label: ____________________

x label: ____________________

b. How did changing the number of turns affect the strength of the electromagnet?

c. What is your conclusion about the relationship between current and the strength of the electromagnet?

d. Look at other groups' electromagnets, data tables, and graphs. Did some electromagnets work better than others? Write down anything you notice that might explain differences in performance.

Name:

23.2 Electromagnets and the Electric Motor

Question: How does a motor work?

1 Getting the rotor to spin

a. When is the right time to reverse the magnet in your fingers? Think about where the magnets are in the rotor.

b. How could you make the rotor spin the other way?

2 Making a 4-pole electric motor

There are no questions to answer in Part 2.

3 Designing and testing different electric motors

Follow the procedures and record your observations below.

4 Measuring current

a. How much current is the motor using when it is spinning? Record your answer in Table 1.

b. Now, measure the current with the rotor stopped (use your finger to stop it). How much current is the motor using when the rotor is stopped? Record your answer in Table 1.

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Table 1: Amount of current used by the motor

Current with rotor stopped (amps)	Current with rotor spinning (amps)

5 Measuring voltage

There are no questions to answer in Part 5.

6 Collecting the data

Table 2: Current and voltage for different motor designs

Number of permanent magnets	Current with rotor spinning (amps)	Current with rotor stopped (amps)	Voltage with rotor spinning (volts)	Voltage with rotor stopped (volts)

Table 3: Power used by the motor

Number of magnets	Power with rotor spinning (W)	Power with rotor stopped (W)

7 Analyzing the data

a. How does the no-load voltage of the battery pack compare with the voltage when the motor is connected and running? How does it compare when the motor is connected but stopped?

b. How does the motor's voltage when it is on but stopped compare to the voltage when it is running?

c. How does the current when the motor is on but stopped compare to the current when it is running?

d. How is the number of permanent magnets used related to the power consumed by the motor?

e. Does the motor use more power when it is running or when it is stopped? Use your observations to explain why electric motors in machines often burn out if the machine jams and the motor is prevented from turning although the electricity is still on.

f. When the motor is running, most of the energy from the battery goes to overcoming friction and adding kinetic energy to the rotor. Where does the energy go when the motor is stopped from turning?

g. How much power does your motor use compared with a 100-watt light bulb? Your answer should show a calculation of how many motors you could run using the electricity used by the 100-watt bulb. Base the calculation on the power used when the rotor is spinning (use any motor configuration).

Name:

23.3 Induction and the Electric Generator

Question: How does a generator produce electricity?

1 Faraday's law of induction

There are no questions to answer in Part 1.

2 Observing the induced current in a coil

There are no questions to answer in Part 2.

3 Building the generator

a. Describe the relationship you observe between the speed of the rotor and the voltage produced.

4 Gathering data

There are no questions to answer in Part 4.

5 Analyzing the data for the alternating poles generator

Table 1: Generator data with alternating magnetic poles facing out

Rotation frequency	Voltage with 2 magnets	Voltage with 4 magnets	Voltage with 6 magnets	Voltage with 12 magnets
40 Hz				
60 Hz				
80 Hz				

a. Use the data from Table 1 to make a graph of voltage versus number of magnets for each frequency. Plot all three sets of data on the same graph. You should have three separate lines on your graph. Clearly label each one to indicate the frequency.

Title: ______________________________

y label: ______________________________

x label: ______________________________

b. How does changing the number of magnets affect the voltage generated? If you double the number of magnets, how much does the voltage change?

c. If you doubled both the number of magnets and the speed, what change would you expect in the voltage?

d. Suppose you had a rotor with a different magnet slot spacing. If you used 16 magnets, what would you expect the voltage to be for each frequency? You should use your graph to answer this question.

e. Why do increasing the rotor speed and changing the number of magnets have a similar effect on the voltage generated? You should mention Faraday's law in your answer.

___

___

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f. Why is it important for the generator coil to be positioned close to the rotor? If you loosen the generator coil screws and slide the coil away from the motor, what happens to the voltage generated?

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6 Changing the orientation of the magnets

Table 2: Generator data with north poles facing out

Rotation frequency	Voltage with 2 magnets	Voltage with 4 magnets	Voltage with 6 magnets	Voltage with 12 magnets
40 Hz				
60 Hz				
80 Hz				

a. Make a graph of voltage versus number of magnets for each frequency.

Title: ___

y label: ___

x label: ___

b. Compare the voltage generated with all north poles facing out to the voltage of the generator with alternating poles facing out. Which design produced the greater voltage overall?

c. Is the difference between the voltage of the two motor designs more noticeable at low or high speeds? Why do you think this is?

d. Compare the voltage created by each design using 12 magnets. Why do you think the generator with all north poles facing out did not work well with 12 magnets?

e. How could you improve the design of the generator? Discuss three improvements you could make that would increase the voltage generated.

Name:

24.1 Semiconductors

Question: What are some useful properties of semiconductors?

1 Building circuits on a breadboard

There are no questions to answer in Part 1.

2 Testing a diode

There are no questions to answer in Part 2.

3 The current versus voltage curve for a diode

Table 1: Positive Voltage vs. Current

Potentiometer Setting	Current (A)	Voltage (V)

Table 2: Negative Voltage vs. Current

Potentiometer Setting	Current (A)	Voltage (V)

a. Showing both positive and negative voltages and currents, draw the current versus voltage graph for the diode.

Title: ______________________________

y label: ______________________________

x label: ______________________________

b. Explain how the graph shows that the resistance of the diode changes with the direction of current.

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4 LED's

The acronym LED stands for Light Emitting Diode. Repeat the experiment in Part 3 except use an LED instead of an ordinary diode and replace the bulb with a 100Ω resistor. Record your data in Tables 3 and 4 below. Graph your results on the next page in the space provided.

Table 3:Positive Voltage vs. Current

Potentiometer Setting	Current (A)	Voltage (V)

Table 4:Negative Voltage vs. Current

Potentiometer Setting	Current (A)	Voltage (V)

Graph you results here:

Title: ______________________________

y label: ______________________________

x label: ______________________________

Name:

24.2 Circuits with Diodes and Transistors

Question: What are some useful properties of transistors?

1 Connections and circuits for a transistor

There are no questions to answer in Part 1.

2 A transistor switch circuit

There are no questions to answer in Part 2.

3 Analyzing the circuit

a. What size resistor did you use for the base of the transistor?

b. Measure the voltage across the base resistor when the transistor is switched on (low resistance). Use Ohm's law to calculate how much current flows into the base of the transistor when it is turned on.

c. Break the circuit at the battery and connect your meter in series to measure the current through the motor when the transistor is turned on.

d. Cover the solar cell and measure the current through the circuit when the transistor is turned off. This current may be too small for your meter to measure; in this case you can only estimate what the maximum current through the circuit could be. The meter rounds measurements to the nearest 0.001 amps. For example, if the meter reads 0.000 A, the maximum current that can be flowing is 0.0005 amps.

e. Reconnect the circuit and measure the voltage across the transistor when it is turned on. Also, measure the voltage across the transistor when it is turned off.

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f. Use Ohm's law to calculate the resistance of the transistor in its "on" state, and record your answer in Table 1.

g. Use Ohm's law to calculate the resistance of the transistor in its "off" state and record your answer in Table 1. If your meter read 0 A, your calculation is really only telling you the *minimum* resistance the transistor could have. The actual resistance could be much higher, making the current through the circuit even smaller than your estimate.

Table 1: Transistor voltage and current measurements

	Motor on	Motor off
Current (A)		
Collector - emitter voltage (V)		
Transistor effective resistance (Ω)		

Name:

24.3 Digital Electronics

Question: How do you construct electronic logic circuits?

1 Digital logic

There are no questions to answer in Part 1.

2 Integrated circuits

There are no questions to answer in Part 2.

3 Building a logic circuit

There are no questions to answer in Part 3.

4 Designing and building some logic circuits

Follow the procedures and record your circuit design and notes in the space below and on the following page.

Extra space for notes and performing calculations: