

6.1

What is a Circuit?



Question: What is an electric circuit?

 **Safety Tips:** Be careful working with batteries. If they are damaged or broken, return them immediately to your teacher.

If a battery or wire gets hot, disconnect the circuit and ask your teacher for help.

Always have a bulb somewhere in your circuit. Do not connect a wire directly from one terminal of the battery to the other terminal. This is a short circuit, which can start a fire.

1

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

Draw your successful and unsuccessful circuit attempts below.

Successful circuits	Unsuccessful circuits

2

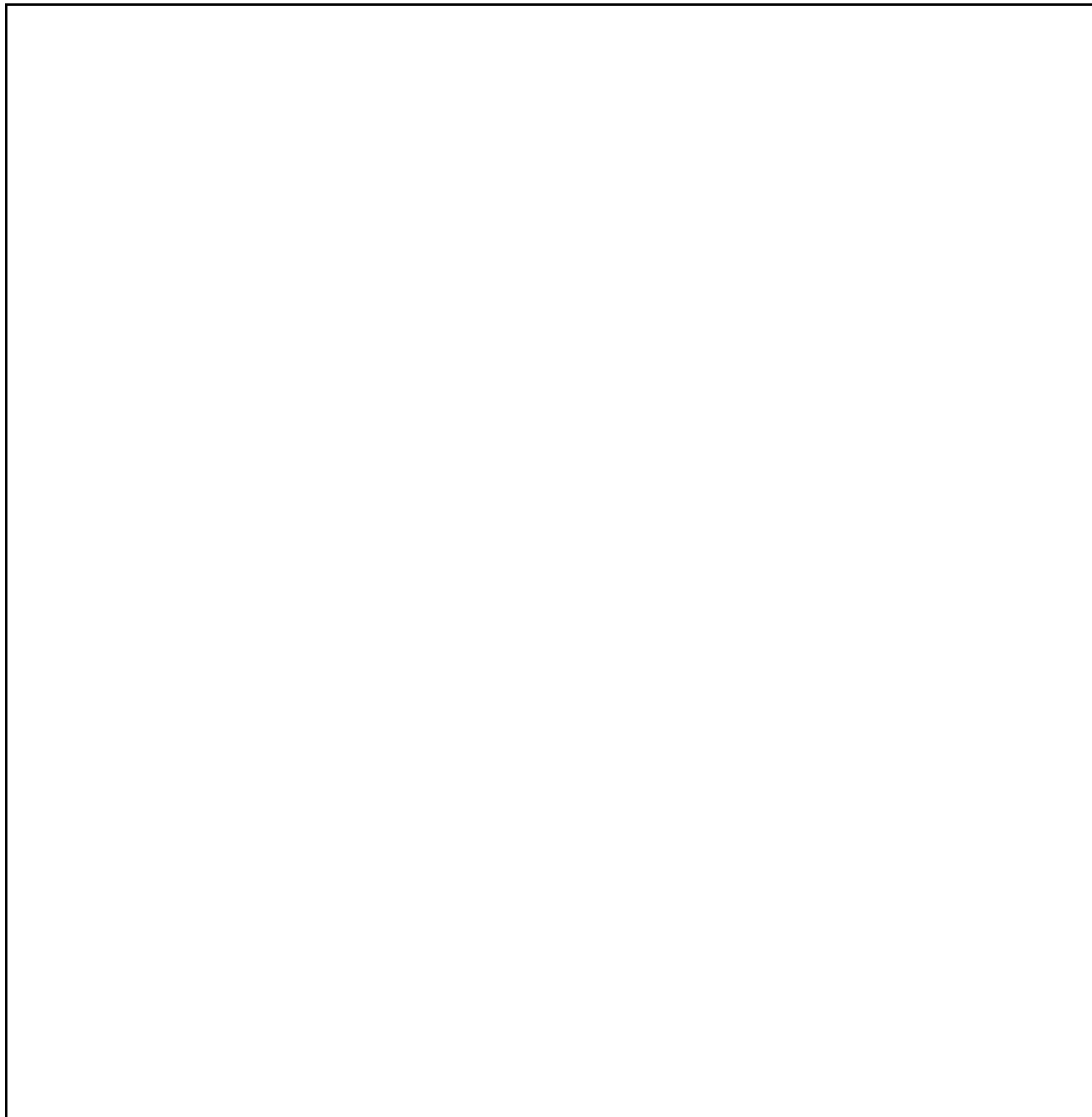
Using the electric circuits set

In this part of the Investigation, you will build the same circuit you made in part 1, except you will now use the electric circuits set. The set includes a small table, battery holders, and light bulb holders, which makes building circuits a lot easier. Your completed circuit should include one battery and battery holder, one bulb and bulb holder, and two wire connectors. The bulb should light up in the completed circuit.

3

Drawing circuit diagrams

Draw your circuit diagram using electrical symbols below.



4

Observing how a switch works

Examine the switch as it turns the light bulb on and off. Below, explain how the switch works. 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 a circuit that is not working is sometimes called an “open circuit.” Based on your observations of the switch, explain what “open” means in a circuit.

5**Observing the interaction between the tapes - part 2**

1. Line up the two electroscope halves so that A and B pieces of tape are parallel to each other. Slowly move the two pieces of clay towards each other.
2. Observe and record what happens to the two pieces of tape.

3. Now see how the A and B tapes interact with the first two pieces of tape you prepared. Record what you observe.

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.

7.1

Voltage



Question: Why do charges move through a circuit?

 **Safety Tips: Be careful working with batteries. If they are damaged or broken, return them immediately to your teacher.**

If a battery or wire gets hot, disconnect the circuit and ask your teacher for help.

Always have a bulb somewhere in your circuit. Do not connect a wire directly from one terminal of the battery to the other terminal. This is a short circuit, which can start a fire.

1 Measuring voltage across a battery

Record the voltage of the battery.

2 Measure voltage across a battery in a circuit

1. Gather the following additional materials: a battery holder, a bulb, a bulb holder, and two connectors.
2. Build a circuit with the battery you just tested, a battery holder, a bulb, a bulb holder, and two connectors.
3. Predict what the voltage of the battery will be while it is lighting the bulb. Also explain the reasoning behind your prediction.

4. Measure the voltage across the battery exactly as you did in part 1. **DO NOT DISCONNECT THE CIRCUIT.**
5. Record the voltage of the battery while it is lighting the bulb.

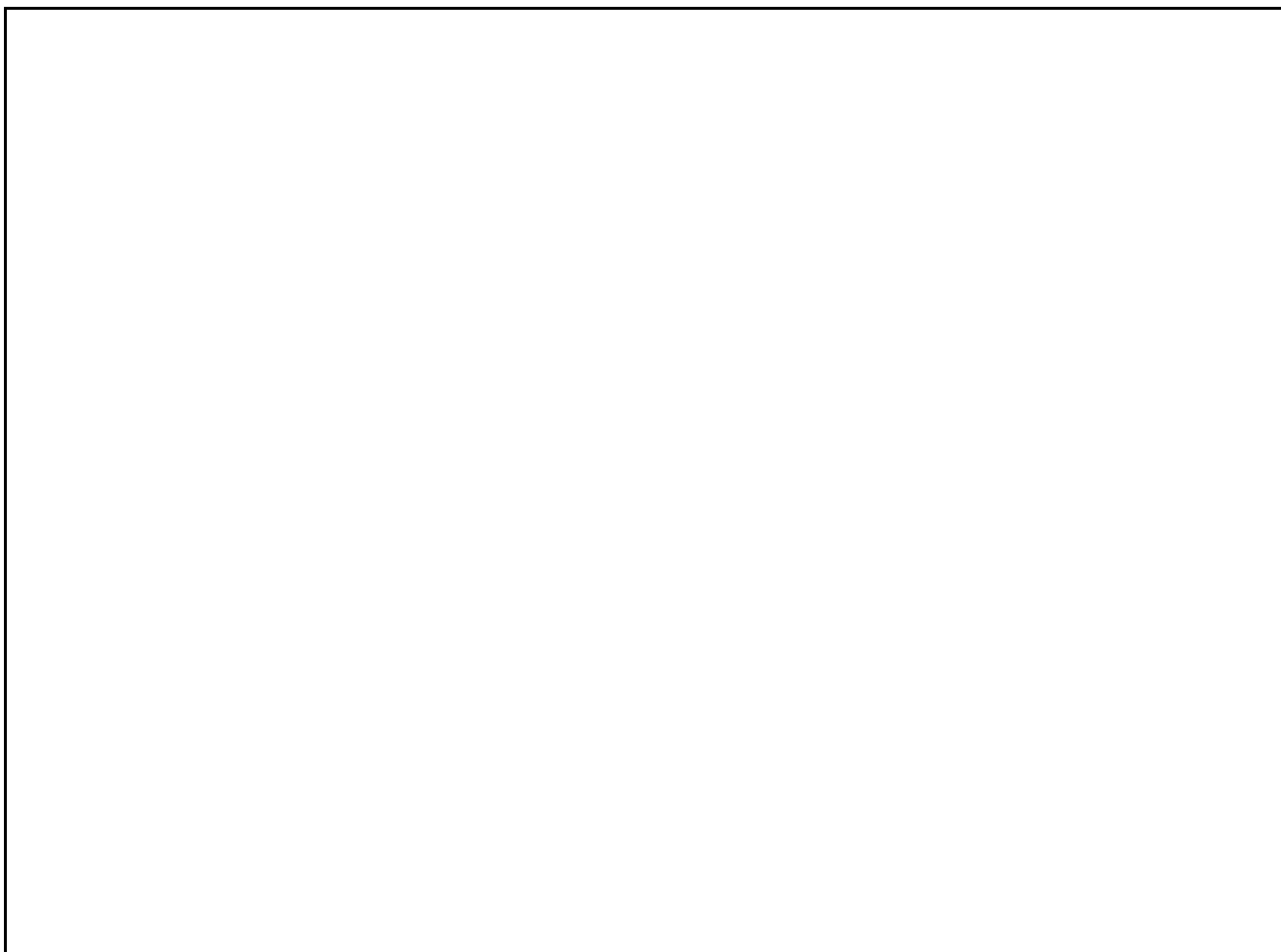
3

What did you learn?

a. Was your prediction correct?

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


c. A battery has chemicals inside that react with each other and release energy. This energy separates and moves the charges to each terminal of the battery. Draw a picture that shows how the charges separate and to which terminals they migrate.



4**Building circuits with two batteries**

Record your data from part 4 in the table below.

Trial	Voltage across both batteries (V)	Do you think the bulb will light? (prediction)	Does the bulb light?	Voltage across bulb (V)

Examine your data in the above table carefully. Then, discuss the following questions with your group and record your answers. 

- a.** Describe in words 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 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.

7.2

Current



Question: How does current move through a circuit?

 **Safety Tips: Be careful working with batteries. If they are damaged or broken, return them immediately to your teacher.**

If a battery or wire gets hot, disconnect the circuit and ask your teacher for help.

1**Building test circuit #1**

There are no questions to answer in part 1.

2**Measuring current through test circuit #1**

1. Connect the two meter leads to the meter as shown.
2. Set the meter to measure DC current at the highest range.
3. Remove the connector between the positive terminal of the battery and the bulb holder.
4. Place the red positive lead of the meter on the post attached to the positive terminal of the battery.
5. Place the black negative lead of the meter on the free post attached to the bulb holder. You should now have a complete circuit. The bulb should light and you should get a reading on the meter.
6. Record the current at point A.

7. Predict what the current at point B will be. Record your prediction.

8. Following the same procedure you did for point A, use your meter to measure current at point B. The positive lead of the meter should be closest to the positive battery terminal, and the negative lead of the meter should be closest to the negative battery terminal.

9. Record the current at point B.

10. Remove the meter and reconnect the circuit. Leave it connected while you complete part 3.

3**Building test circuit #2**

There are no questions to answer in part 3.

4**Comparing test circuits #1 and #2**

Compare the brightness of the bulbs in test circuits 1 and 2. Record your observations and disconnect test circuit 1.

5**Measuring current through test circuit #2**

1. Using the same procedure you followed in part 2, measure and record current at point A.

2. Predict what the current will be at points B and C.

3. Using the same procedure you followed in part 2, measure and record current at points B and C.

6**What did you learn?**


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.

	Current in circuit 1 (amps)		Current in circuit 2 (amps)
point A		point A	
point B		point B	
		point C	

What happened to current when you added a bulb to the circuit?

- d. You probably determined that adding a bulb to the circuit reduced the current. With the rest of your group propose an explanation. Be prepared to present and defend your explanation. 

Extra space for notes:

7.3

Resistance



Question: How well does current travel through different materials and objects?

1

Measuring resistance of everyday objects

Follow the procedures for part 1 and record all resistances in the table below.

Table 1: Resistance of common objects

Object	Material, if known	Resistance in ohms

2**Identifying conductors and insulators**

Follow the procedures for part 2 and record your data in the table below.

Table 2: Classifying materials as conductors, insulators, or semiconductors

Object / material listed from low to high resistance	Resistance in ohms (from Table I)	Conductor, insulator, or semiconductor	Was your classification correct?

3**Measuring and comparing resistance of copper and aluminum**

- a. Your teacher will give you two identical wires of aluminum and copper. Which metal do you think will have more resistance? Why?

- b. Measure the resistance of both pieces of metal. You can bend the wire so that the meter leads can reach the ends. Record your results.

- c. Which metal has the lowest resistance? Do you know if this metal is commonly used in electric circuits?

- d. Fold each piece of wire neatly in half and mark the halfway point. Unfold the wire and measure resistance from the halfway point to one end of the wire. Record your results for copper and aluminum.

e. Compare the resistance for the whole piece of each metal with the half piece. How does resistance vary with length?

f. How do you think resistance of a wide wire will compare with that of a thin wire of the same length? Discuss this question with your group and record your answer. Think about the flow of water through narrow and wide pipes.

Name:

8.1

Ohm's Law



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

1

How does changing resistance affect current?

Build a circuit with two batteries, one bulb, the switch and your potentiometer. Record what happens when you turn the dial.

Record your data from part 1 in the table below.

Table 1: Change in current vs. change in resistance for a potentiometer

potentiometer setting	current (amps)	resistance (ohms)
First potentiometer setting		
Second potentiometer setting		
Third potentiometer setting		
Fourth potentiometer setting		
Fifth potentiometer setting		

Examine your data. Describe in words what happens to current as resistance is increased.

2**How does changing voltage affect current?**

Record your data from part 2 in the table below.

Table 2: Change in voltage vs. change in current for a resistor

potentiometer setting	resistance (ohms)	current (amps)	voltage (volts)
First potentiometer setting			
Second potentiometer setting			
Third potentiometer setting			
Fourth potentiometer setting			
Fifth potentiometer setting			

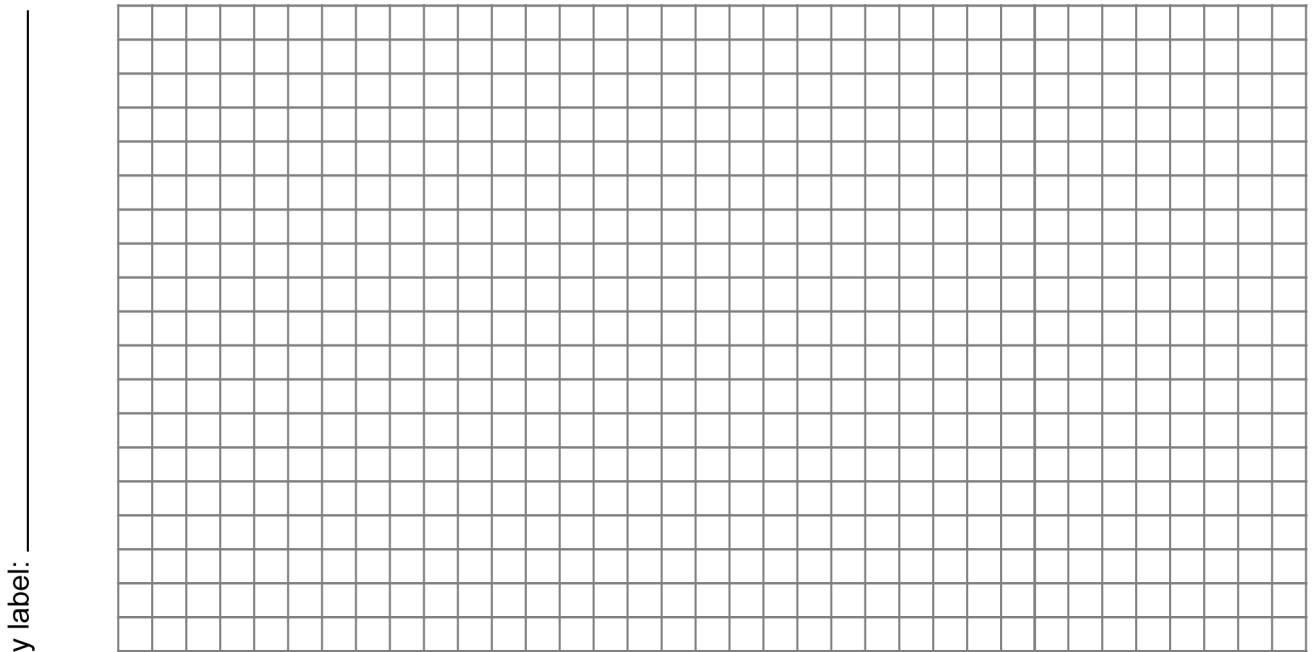
Examine the data in your table. Describe in words what happens to the voltage across the resistor as the current increases.



Finding the relationship between voltage, current, and resistance

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

Title: _____



- b. The slope of a line is rise over run. For the graph of voltage vs. current, slope is change in voltage (rise) over change in current (run). Calculate the slope of the graph. Show your work below.

What other electrical quantity in the circuit does the slope approximately equal?

- c.** You just found out that the slope of the voltage vs. current graph is the resistance. This is the equation for Ohm's law. Write the mathematical equation for Ohm's law using the following:
V stands for voltage, **I** stands for current, and **R** stands for resistance. Show your work below.

- d.** Most circuits use fixed voltage sources. Different values of current are needed to run different devices and appliances. With this information, explain the importance of resistors in a circuit.

8.2

Work, Energy, and Power

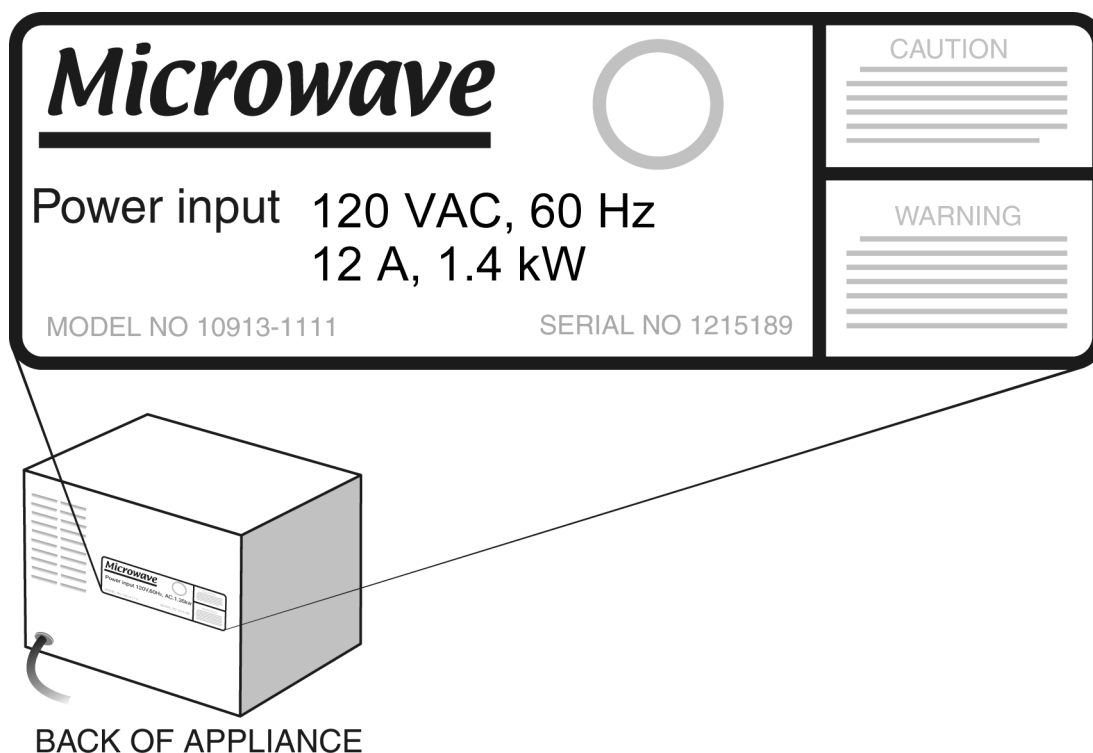


Question: How much does it cost to use the electrical appliances in your home?

1

Find the power rating of home appliances

You will need to complete the first part of this Investigation at home. Your assignment is to find five electrical appliances that have a label with the device's power rating in watts or kilowatts. Some appliances you might investigate are a blender, coffee maker, toaster oven, microwave, television, hair dryer, space heater, room air conditioner, or an electric drill. The rating is often stamped on the back or the bottom of the appliance.



In the above example the power rating is 1.35 kW.

1. 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.
2. Convert any power ratings listed in watts to kilowatts. To convert to kilowatts, divide the number of watts by 1,000. For example, 1500 watts is equal to $1500 \div 1000$, or 1.5 kilowatts. Fill in the kilowatt column for each device.
3. Finally, 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 one-half hour times 30 days equals 15 hours per month. You may need to talk to other people in your home to get the most accurate estimate possible.
4. After you have filled in the estimated monthly use column, you are ready to complete the rest of the Investigation in class.

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

Appliance	Power rating in kilowatts	Estimated hours per month in use	Number kWh per month	Price per kWh	Total cost per month

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

In order to determine how much your household spends each month to use some of your appliances, you must first calculate the number of kilowatt-hours expended per month.

To do so, simply multiply the power rating in kilowatts (from the second column) by the number of hours the appliance is used each month. If you use a 1-kilowatt toaster for five hours a month, you would multiply 1 times 5.

Write your answers in column 4 of Table 1, as shown in the sample below.

Appliance	Power rating in kilowatts	Estimated hours per month in use	Number kWh per month	Price per kWh	Total cost per month
Microwave	1.35 kW	22 hours	29.7		

3 Determine the monthly cost of using your appliances

Utility companies charge consumers for the number of kilowatt-hours of electricity they use each month. Many houses and apartments have a meter attached to the outside of the building. The meter uses a system of spinning disks to record how much electricity you use. Someone from the electric company reads the meters once each month.

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

- Research your area and write the price per kilowatt-hour in column 5 of Table 1.
- 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 in order 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.

Table 2: Appliances with the highest power ratings

Appliance	Power rating in kilowatts

- b. Think about the function of each appliance listed above. 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 they?

- 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 electrical 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.

What do you buy from the electric utility company?

People often use the phrase “power plant” to refer to their local electric company. You may have heard people say that electric companies “sell power” to their customers, or that there was a “power shortage” in a particular area. Let’s take a look at these phrases from a scientific perspective. What, exactly, do electric companies sell?

We know that electricity bills charge for the number of kilowatt-hours (or kWh) used per month.

Let’s first change kilowatt-hours to the units of watts and seconds:

$$1 \text{ kilowatt}\cdot\text{hour} \times \frac{1000 \text{ watts}}{\text{kilowatt}} = 1000 \text{ watt}\cdot\text{hours}$$

$$1000 \text{ watt}\cdot\text{hour} \times \frac{3600 \text{ seconds}}{\text{hour}} = 3,600,000 \text{ watt}\cdot\text{seconds}$$

(You may remember from previous study of fractions that a term appearing in both the numerator and denominator will cancel when the fractions are multiplied.)

Power is equal to the amount of work done per unit of time, or the amount of energy transferred in a circuit per unit of time. In specific units, a watt is equal to joules per second. We substitute the fundamental units of joules per second for watts.

$$3,600,000 \left(\frac{\text{joules}}{\text{second}} \right) \cdot \text{seconds} = ?$$

- Which terms in the last equation will cancel?

- After canceling the terms that appear in both the numerator and denominator, what is the fundamental unit that remains?

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

- Do electric companies sell energy, work, or power?

9.1

Types of Circuits



Question: What kinds of electric circuits can you build?

Safety Tips: Be careful working with batteries. If they are damaged or broken, return them immediately to your teacher.

If a battery or wire gets hot, disconnect the circuit and ask your teacher for help.

Always have a bulb somewhere in your circuit. Do not connect a wire directly from one terminal of the battery to the other terminal or you will make a short circuit.

1

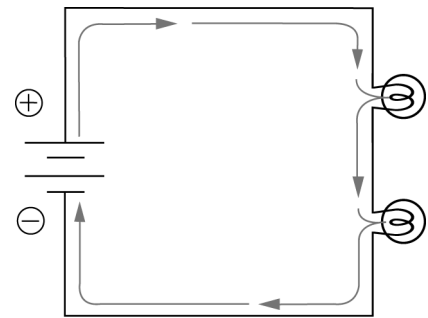
Building two kinds of circuits

- Gather the following materials: two batteries and battery holders, two bulbs and bulb holders, and six connectors.
- Build Circuit 1 pictured at right.
- Trace the circuit path with a pencil from positive terminal to negative terminal. Does the current have any choice about where to go?

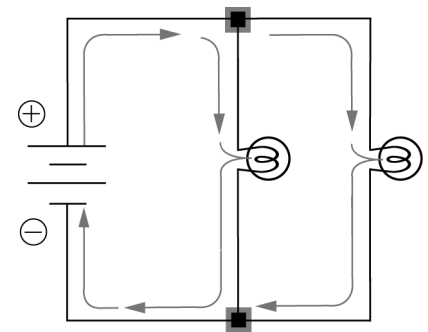
a.) Describe the brightness of the two bulbs.

- Build Circuit 2 pictured at right. The circuit “branches” at the square dots. If you are not sure how to build this configuration, ask your teacher for help.
- Trace the circuit path with a pencil from positive terminal to negative terminal. Does the current have any choice about where to go?

b.) Describe the brightness of the two bulbs.



Circuit 1 (series circuit)



Circuit 2 (parallel circuit)

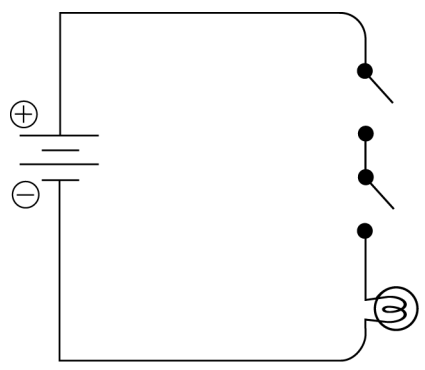
An application of series and parallel circuits

Many circuits include multiple switches that are arranged in both series and parallel combinations. What is the purpose of these combinations?

If two switches are arranged in series, then both switches must be on for the circuit to work. This type of arrangement is called an **AND circuit**. If two switches are arranged in parallel, then only one switch needs to be on for the circuit to work. This type of arrangement is called an **OR circuit**.

Building an AND circuit

1. Gather the following additional materials: two switches and one connector. Build Circuit 3 pictured to the right.
2. Is this a series or parallel circuit? _____
3. Place a label next to each switch. Label one of the switches 1 and the other switch 2.
4. Try all combinations of switches: both on, both off, #1 on and #2 off, and #2 on and #1 off.
5. Record what happens to the bulb in each case:

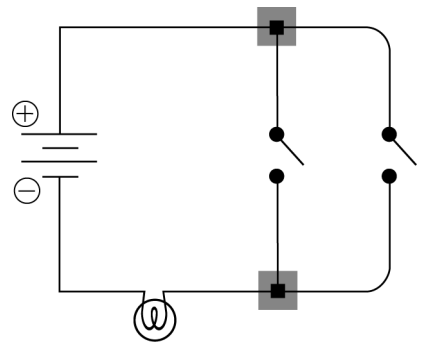


Circuit 3 (AND circuit)

Both on: _____ Both off: _____
 #1 on, #2 off: _____ #2 on, #1 off: _____

Building an OR circuit

1. Build Circuit 4 pictured to the right.
2. Is this a series or parallel circuit? _____
3. Place a label next to each switch. Label one of the switches 1 and the other switch 2.
4. Try all combinations of switches: both on, both off, #1 on and #2 off, and #2 on and #1 off.
5. Record what happens to the bulb in each case.



Circuit 4 (OR circuit)

Both on: _____ Both off: _____
 #1 on, #2 off: _____ #2 on, #1 off: _____

A car will sound a warning bell if you open the door while the lights are on. Is this circuit an AND circuit or an OR circuit? Explain your reasoning.

Space for additional notes:

9.2

Series Circuits



Question: How do you use Ohm's law in series circuits?

⚠ Safety Tips: Be careful working with batteries. If they are damaged or broken, return them immediately to your teacher. If a battery, resistor, or wire gets hot, disconnect the circuit and ask your teacher for help.

Always have a bulb or resistor somewhere in your circuit. Do not connect a wire directly from one terminal of the battery to the other terminal. This is a short circuit, which can start a fire.

1

Adding resistors in series circuits

Follow the procedures and record your data in Table 1.

Table 1: Voltage and resistance values of your parts

R1 Resistance (ohms)	R2 Resistance (ohms)	R3 Resistance (ohms)	Battery voltage (volts)

Follow the procedures and record your data in Table 2.

Table 2: Measurements of current when resistors are added in a circuit

	Circuit with R1	Circuit with R1 and R2	Circuit with R1, R2, and R3
Current in amps			
Resistance in ohms			

Study your calculated resistances in Table 2. What is the rule for calculating total resistance in a series circuit, from individual resistances?

2**Building a circuit with a dimmer switch**

Can you think of other dials that turn that might have a potentiometer inside? With your group, list possible potentiometers. For each example in your list, explain why changing resistance is useful.

3**Finding the resistance of a bulb**

Follow the procedures and record your data in Table 3.

Table 3: Resistance of a bulb at different levels of current

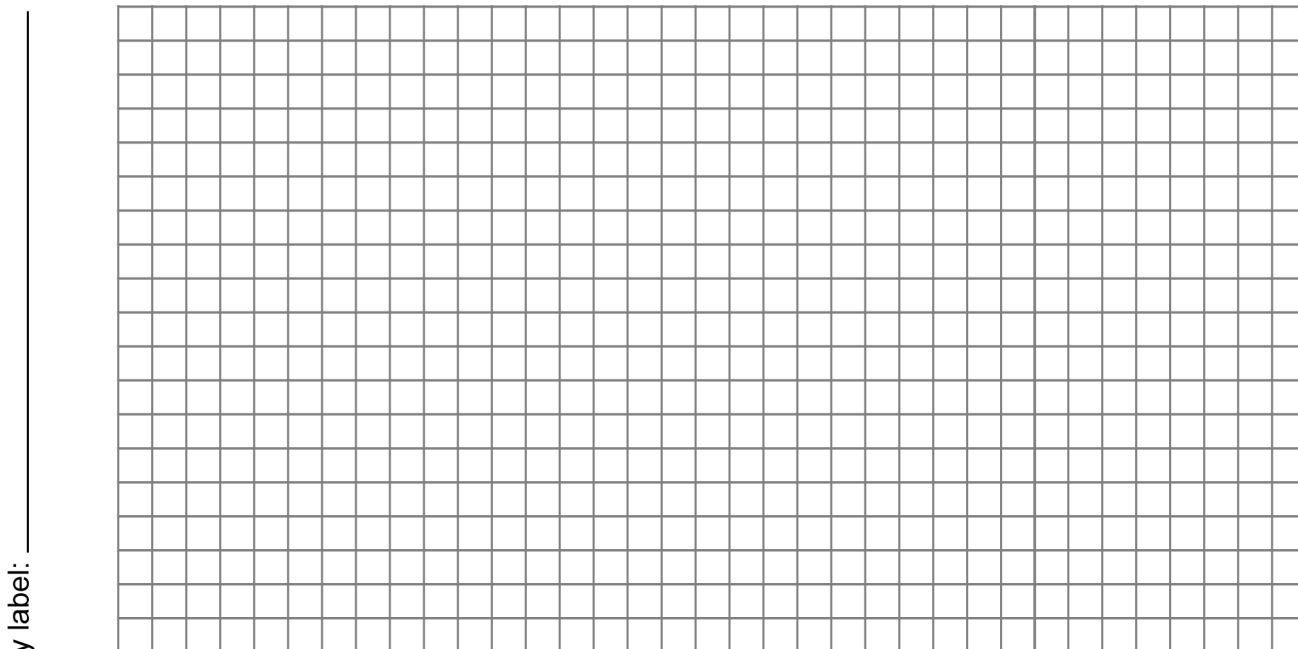
Potentiometer setting	How bright is the bulb?	Bulb voltage (volts)	Current (amps)	Bulb resistance (ohms)
First setting				
Second setting				
Third setting				
Fourth setting				
Fifth setting				

a.



Graph bulb resistance vs. current for each potentiometer setting. Label your axes and title your graph. (Keep this graph for use in your next Investigation.)

Title: _____



x label: _____

b. What happens to bulb resistance when current is higher? Write down your observations about the graph below.

c. At higher temperatures, the tungsten atoms in the light bulb filament move around more. With your group, propose an explanation for why resistance of tungsten increases with temperature.

Extra space for notes:

9.3

Parallel Circuits



Question: How do parallel circuits work?

 **Safety Tips:** Be careful working with batteries. If they are damaged or broken, return them immediately to your teacher.

1 Measuring current and voltage in a parallel circuit

Series Circuit

Follow the procedures and record your data in the table below.

Parallel Circuit

Follow the procedures and record your data in the table below.

Series circuit		Parallel circuit	branch 1	branch 2
Current		Current		
Voltage drop		Voltage drop		
Resistance		Resistance		

2 What did you learn?

- a. Compare the current, voltage drops, and resistance in the series circuit with the parallel circuit. What do you notice?

4**Building a test voltage circuit**

- a. Use one battery, one bulb, and your potentiometer to build a dimmer light circuit. Slowly decrease resistance until the light bulb goes out. Measure and record current.

- b. Study the test voltage circuit diagram. What is the voltage drop across each branch?

- c. What will be the voltage drop if the total battery voltage drops to 80 percent of its original value? Show your work below.

- d. Use Ohm's law to calculate the *total* resistance needed in the second branch of the test voltage circuit. This is the resistance that will cause the bulb to go out at 80 percent of the battery voltage! Use the voltage from step 4(c) and the current from step 4(a) to calculate total resistance. Show your work below.



e. Use the graph of bulb resistance vs. current from the last Investigation to figure out the bulb resistance at the current you measured in step 4(a).

f. Calculate the unknown resistance shown in the test voltage circuit. You know the total resistance from step 4(d) and the bulb resistance from step 4(e). Show your work below.

g. Build the test voltage circuit. Use a 10-ohm resistor to represent the medical device. Before adding the potentiometer to the circuit, set it to the resistance you calculated in step 4(f). If your batteries are fully charged, the bulb should light when you turn on the switch! Record your results.

h. Your teacher will give you some used batteries. Label them and place them in your circuit. See if the light is off when you turn the switch! Record your results.

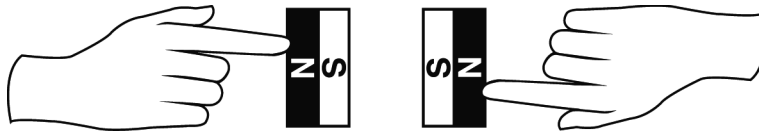


Question: What effects do magnets have?

1

Describing the forces that two magnets exert on each other

- a. Try holding two magnets with their south poles facing each other. What happens?



- b. Try holding two magnets with their north poles facing each other. What happens?



- c. Try holding two magnets with north and south poles facing each other. What happens?



- d. Write down a rule that describes how magnets exert forces on each other. Your rule should take into account your observations from steps a-c, and should use at least two of the following words: attract, repel, north, south, and pole.

2

Determining how far the magnetic force reaches

How far does the magnetic force of a magnet reach? This is an important question for machines that use magnets.

Follow the procedures and record your data in Table 1.

Table 1: Magnetic forces between two magnets

	N-S	S-S	N-N
Distance 1			
Distance 2			
Distance 3			
Average distance			

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 larger than the precision of your measurement.

The word “magnetic” is used to describe things that are affected strongly by magnets. Look at your data table. How would you describe the things that are magnetic and the things that are not? Use the following words in your answer: magnetic and nonmagnetic.

4

Do nonmagnetic materials affect the magnetic force?

Follow the procedures and record your data in Table 3.

Table 3: Testing nonmagnetic materials

	N-S	S-S	N-N
Distance 1			
Distance 2			
Distance 3			
Average distance			

What did you find out about how magnetism is affected by nonmagnetic materials? Use the words *force* and *distance* in your answer.

b. Perform the two tests. Record your observations.

c. Does the electromagnet act like a permanent magnet? Write down your conclusion and how you arrived at it.

3 **The right hand rule**

a. Determine the direction of current through the electromagnet. (The current flows from the positive terminal to the negative terminal.)

b. Use the right hand rule to determine the north and south poles of your electromagnet. Record your answer with a drawing below.



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

Follow the procedures and record your results in the table.

Number of batteries	Current (in amps)	Number of paper clips picked up
1		
2		
3		

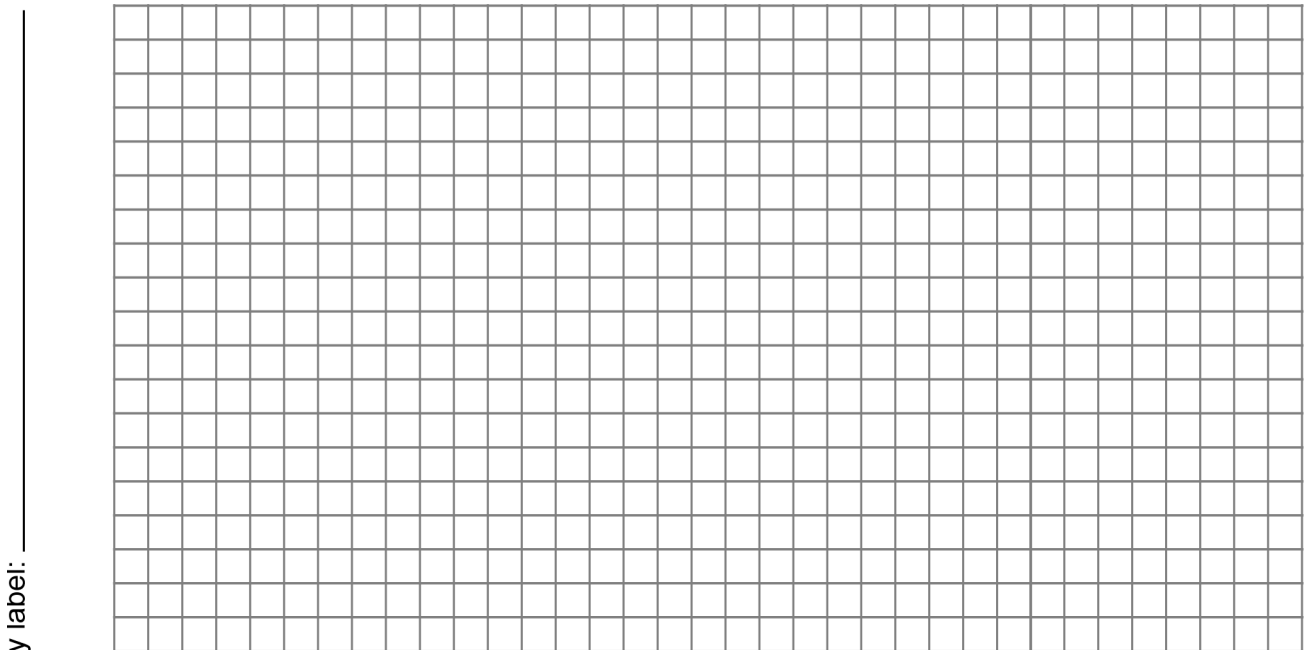
5**What did you learn?**

a.



Draw a graph showing how the number of paper clips picked up by the magnet varies as the current is increased. Answer the following questions first: Which variable goes on the x -axis? Which variable goes on the y -axis?

Title: _____



y label: _____

x label: _____

b. Label your axes and title your graph.

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

d. Prepare a poster summarizing the results of this experiment. Include your data table and graph on the poster. Display your electromagnet with your poster.

e. 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: _____

10.3

Electric Motors and Generators



Question: How does an electric motor or generator 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 in the rotor are.

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

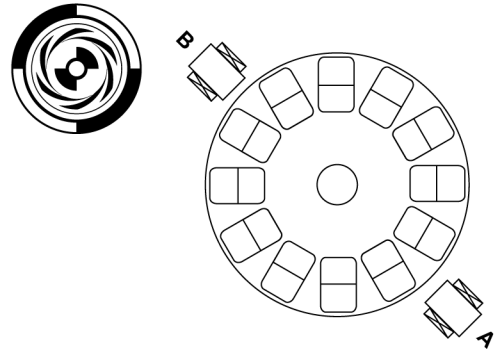
2 Making a 4 pole electric motor

There are no questions to answer in part 2.

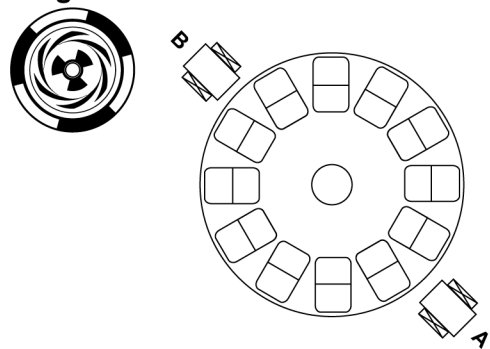
Designing and testing different electric motors

Use the design charts to record your design, including the direction (north and south) and position of all magnets. Put an X where you placed the electromagnet. Record only designs that worked.

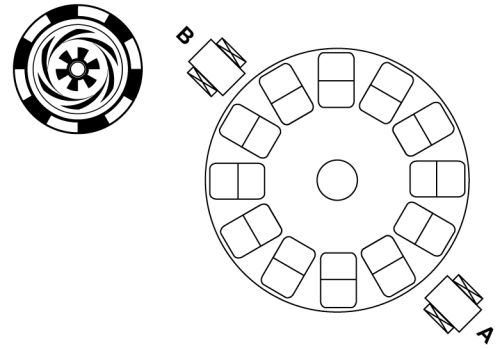
Pink Disk



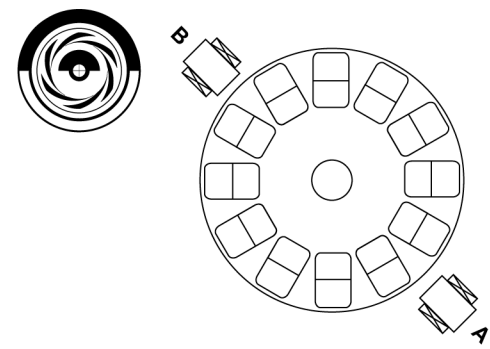
Orange Disk



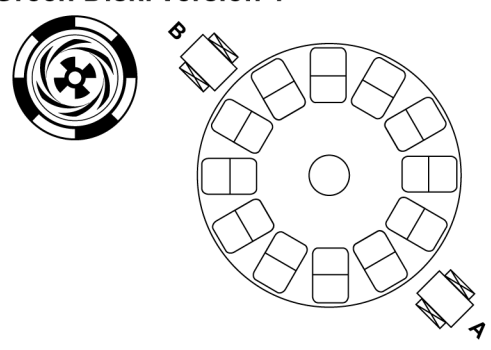
Blue Disk



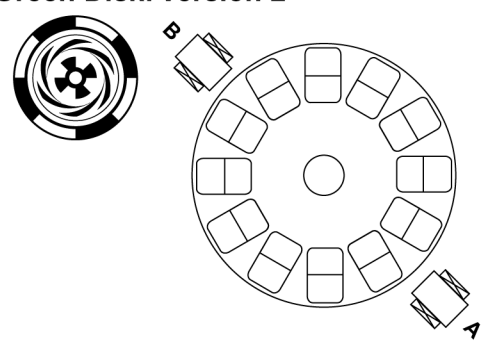
Yellow Disk



Green Disk: Version 1



Green Disk: Version 2



4 Testing for Performance

- a. Which motor design gave you the highest speed and why do you think it was higher than the others? Your answer should identify the commutator disk and number of magnets you used.

- b. What variables did you adjust that had an effect on the speed? Can you give any explanation for why you think the variables you adjusted made a difference to the speed?

- c. What would happen to your speed comparisons if the batteries were fully charged for the first trial but slowly lost their power later in the experiment?

- d. Can you think of a way to be sure the experimental results were not affected by the draining of the batteries? Write down a procedure that would give you a way to check whether the batteries were still the same all through the experiment.

5**How much electricity does a motor use?**

Record your measurements and data from part 5 in the table below.

Table 1: Electrical measurements

	Motor on & stopped		Motor on and running
Voltage (volts)		Voltage (volts)	
Current (amps)		Current (amps)	

- a. Is there a difference in the voltage with the motor stopped compared to when it is running?

- b. Is there a difference in the current with the motor stopped compared to when it is running?

- c. Power is equal to voltage times current. Calculate the power used by the motor when it is on but stopped, and also when it is on and running. Record your answers in the table below.

Table 2: Power calculations

	Motor on & stopped		Motor on and running
Power (watts)		Power (watts)	

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

e. When the motor is running, the energy goes to overcoming friction and adding kinetic energy to the rotor by making it go faster. Where does the energy go when you stop the motor from turning but the electricity is still flowing?

f. How much power does your motor use compared to 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.

g. The horsepower is the average power that could be produced by a working horse. One horsepower is equal to 746 watts. Electric motors are usually rated in horsepower. For example, a table saw might have a 1.5 horsepower electric motor. Calculate how many horsepower your motor makes. Show your work below.

Record all the data in the table below.

Table 3: Electric generator data (AC volts)

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

Look at your measurements and compare the voltages you got with different numbers of magnets and different speeds.

a. How does increasing the speed affect the voltage generated? If you double the speed, how much does the voltage change?

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?
