

Question – How can breadboards and simple circuits be used in engineering and science?

Hypothesis – If the energy needed to power specific circuits can be measured, then these individual observations can be used to formulate an idea of the total energy needed to power a home or town.

Materials -

Voltmeter with testing leads	Breadboard
Light Diodes	AC/DC Inverter Set up with connector wires
Ruler	Jumper Wires
1 Capacitor	6 Resistors
Diodes	Oscilloscope

Procedure

Part 1- Set Up

1. The main portion of the module includes a plexiglass baseplate, a hand-operated wheel assembly, a 3D-printed magnet container, a magnet-bearing steel shaft, a voltmeter, an oscilloscope, and an electrical circuit board known as a “breadboard”. The system overview is demonstrated below in Figure 1.

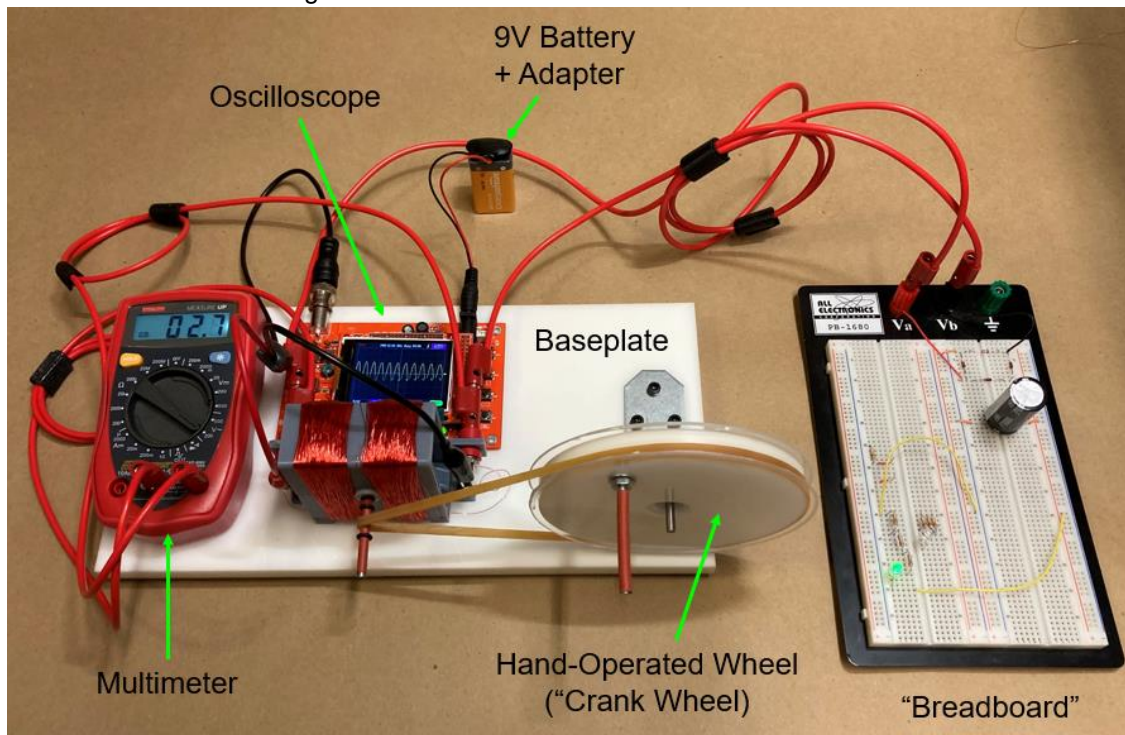


Figure 1. Full system assembly.

2. The oscilloscope should be first plugged into the 9 V battery with the included adapter. The oscilloscope has another plug with two wires. These two clips—the alligator clips—can be clipped

onto metal portion of the banana jacks on the magnet container. The oscilloscope is shown below.

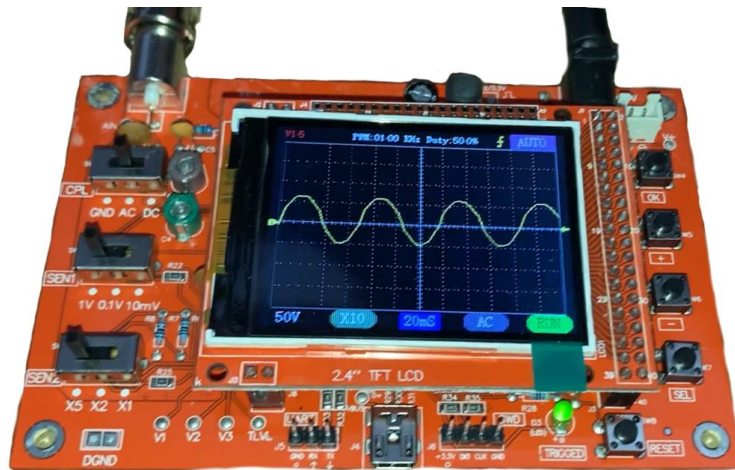


Figure 2. Oscilloscope measuring an alternating current signal.

3. Next the breadboard must be connected. For each of the two wires, plug one end into the port that is opposite of where you clipped to the oscilloscope on the inverter box. The free two ends of the wires can be plugged into the red and black ports of the breadboard. It does not matter which order you choose. The setup should look as shown below.

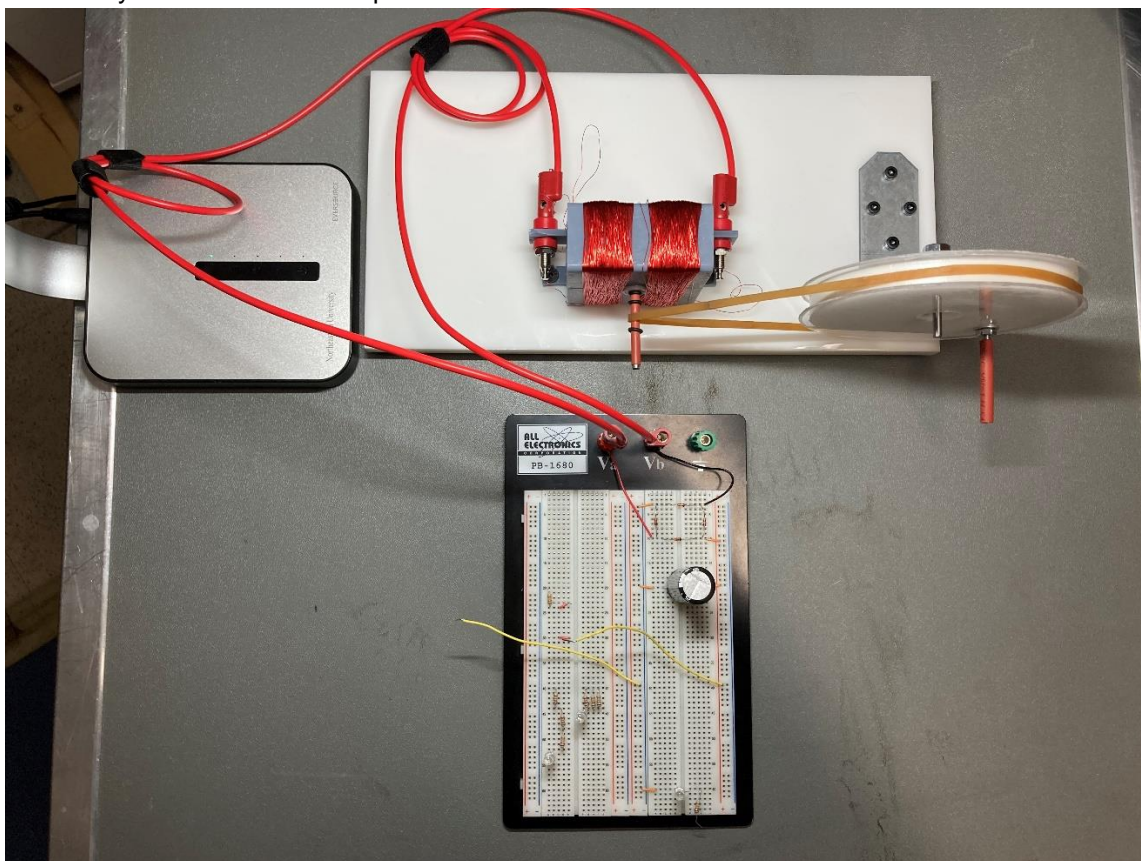


Figure 3. Connection of electrical generator to breadboard.

4. Measure the diameter of the crank wheel. Be sure to measure the diameter of the white inner portion of the wheel rather than the larger clear outer regions. This will act as the “large gear” in

this system. Be sure to use consistent units! In other words, stick to using either inches, centimeters, or millimeters for both measurements.

Large gear diameter: _____

Measure the diameter of the metal shaft protruding from the magnet container. This will serve as the "small gear" in this system.

Small gear diameter: _____

5. Divide both of the values above by the small gear diameter. Use the resulting value to express the ratio of the large gear diameter to the small gear diameter

Gear ratio: _____

6. Wrap a rubber band around large gear and small gear. Spin the large gear to make sure that the small gear is able to rotate freely. Record observations about the relative rotational speeds of the gears. Try counting the number of times the magnets turn for every one turn of the large crank wheel. Similarly, make note of how fast the small gear moves relative to the large gear.

7. As you spin the gears, look at the oscilloscope. What shape does the line of the graph take?

Shape of oscilloscope: _____

Note: The bottom left shows that each line on the y-axis maximum is 5V. Each line on the x-axis total is 20 mS. This allows you to measure multiple amplitude (distance of the line above the x-axis) and frequency.

The waves you discovered are called Sine Waves. Each wave is the distance between one crest to the next crest.

8. At this time, measure the voltage. This can be done by setting the voltmeter at 200 past the ~V on the dial. This will read AC current. This can be done by plugging in the clips directly into ports the magnetic component. AC current just means the current is moving forward and backwards.

9. Pick three speeds at which to spin the crank wheel. As a suggestion, aim for approximately $\frac{1}{4}$ turn per second, $\frac{1}{2}$ turn per second, and 1 turn per second. For each speed, how many complete sine waves are shown on the oscilloscope? The frequency of the sine waves directly reflects the rotational speed of the magnets. What do you notice about the amplitude as the frequency increases?

	Approximate rate of large wheel (turns / s)	Number of Sine Waves	Amplitude (V)
<u>Trial I – Slow Spin</u>			
<u>Part II – Medium Spin</u>			
<u>Part III – Fast Spin</u>			

10. You can convert the number of Sine Waves into the rotational speed (revolutions per second) of the magnet pair. The magnet pair will generate two sine waves for every one full revolution. Additionally, the number at the bottom middle of the oscilloscope should be 50 ms by default. This means you are seeing the number of sine waves generated in 0.050 seconds. In order to convert this value to seconds, you need to multiply by 20. Since there are two sine waves for every one full rotation, you also need to divide the number of sine waves by 2. Therefore, the rotational speed (in revolutions per second) of your magnet pair can be calculated as follows:

$$\text{Rotational speed} \left(\frac{\text{rev}}{\text{s}} \right) = (\# \text{ of sine waves}) \times 10$$

11. You can use the information you just recorded above to see how fast you were actually turning the large wheel. Since you know the gear ratio based on the measurements you took previously, you can multiply your rotational rate (Answer from Step 10) of the magnet pair by the inverse (flipped version) of the gear ratio to get the *actual* rotational speed of your large wheel:

$$\text{Rotational speed of large wheel} = (\text{Measured rotational speed of magnets}) \times \left(\frac{1}{\text{gear ratio}} \right)$$

12. Now it is time to build a bridge rectifier. A bridge rectifier will convert the mechanical energy from spinning the gear into usable electrical energy. The bridge rectifier consists of 4 diodes in a square shape. These diodes have black stripes on one end. Electricity cannot enter through the black-stripe end. So the diagram must be built exactly like the figure below. The schematic for a bridge rectifier is also below. Make sure that the opposite sides of the squares match what side the black line is on. (Bonus: map out the pathway of electricity in the schematic below. Use the color-coded arrows as a visual guide)

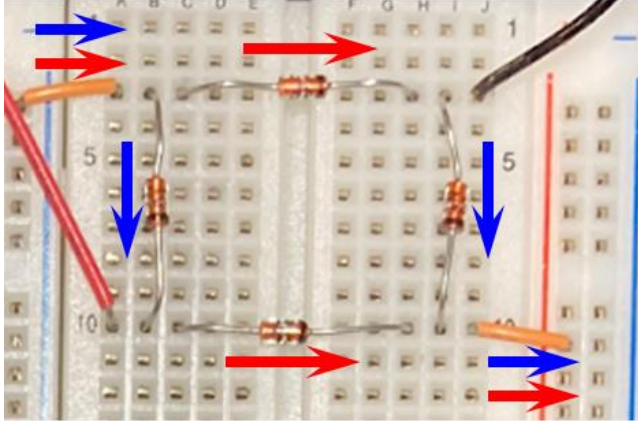


Figure 4: Bridge rectifier with schematic

13. As seen in the figure above, there are the two wires connected from the breadboard ports (red and black). There are also two jumpers or short wires. At the bottom of the square, one of the breadboard wires must be plugged in the same row as the corner of a bridge rectifier, diagonal to the other breadboard wire connected in the same row of the opposite corner.

14. Match the figure down below (Note: to set up the capacitor, one of the legs will be longer than the other. Bend the longer leg such that it has the same length as the shorter leg.)

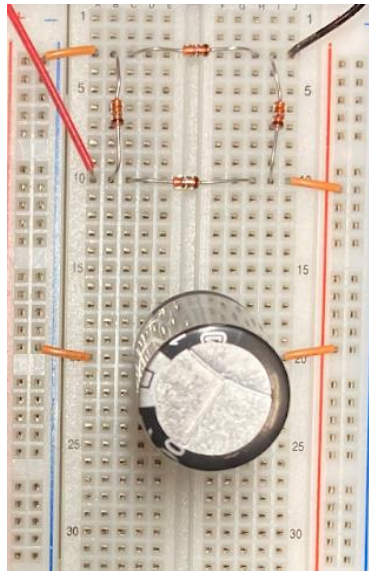


Figure 5: Power source plus bridge rectifier circuitry

15. This is the energy source for your circuits throughout the rest of the lab. Connect the oscilloscope to the capacitor using the clips. As you spin the gears, look at the oscilloscope. What shape does the line of the graph take now? Is the shape of the line different from when there was no bridge rectifier involved?

Shape of oscilloscope: _____

The shape of the oscilloscope proves that you changed an AC current to a DC current. IF you remember, AC current means that the current moves in both ways. DC current means that the current only moves one way.

Circuit Analysis Part 1 - Building a series circuit

You will now build your first simple circuit.

1. The two long yellow jumper cables will be used to provide power to your series circuit. Three resistors will be needed for each circuit.
2. Construct the breadboard so that it looks like the image below. There are two circuits on this breadboard. Using the jumpers will allow you to connect to one circuit or another. There is also a zoomed in photo of the series circuit.

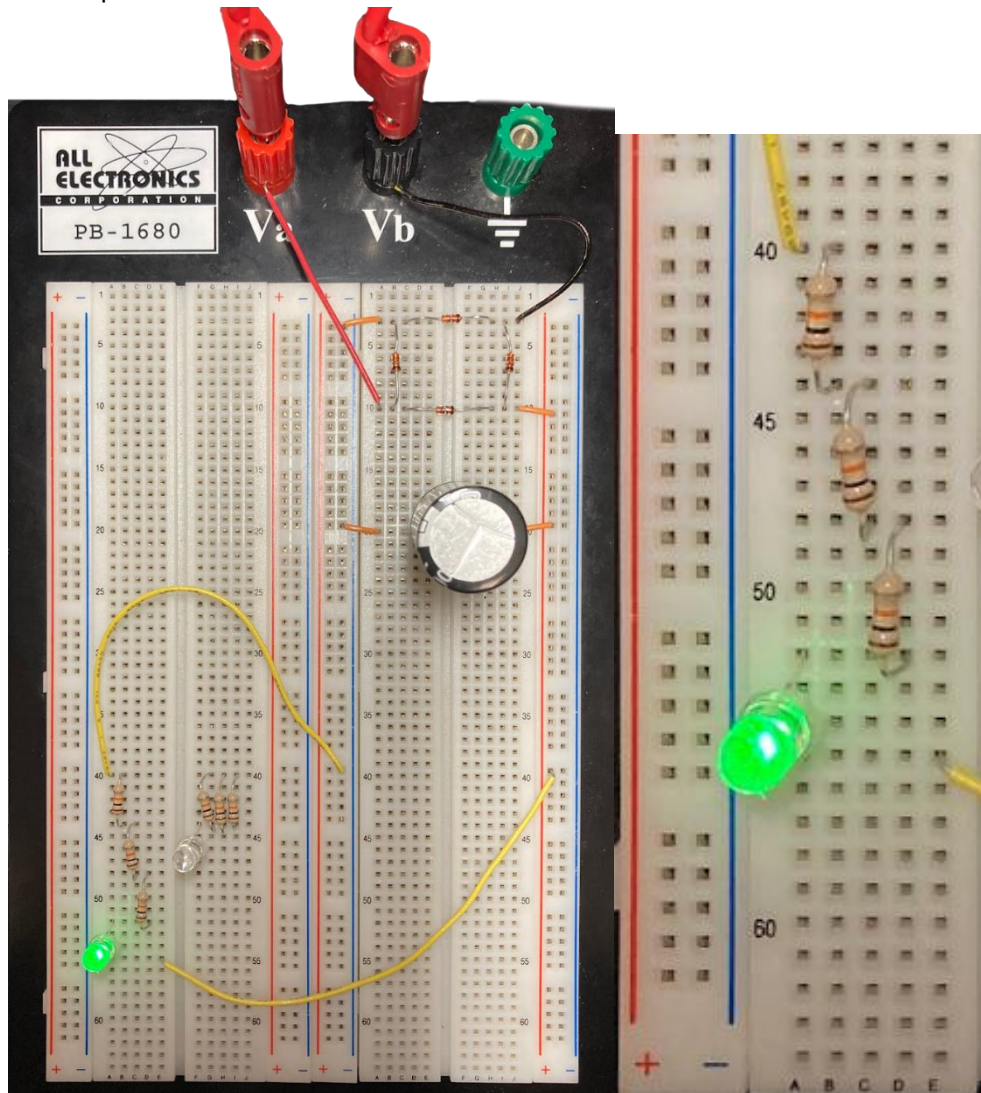


Figure 6: Full breadboard circuitry with zoomed in picture of a series circuit

3. Spin the gear and watch as the LED lights up. Take note as you increase speed of the gear and the brightness of the lights.
4. Use the voltmeter and the end clips, to clip to each of the push-in terminals. The push-in terminals are just the small pieces of metal. Set one push-in terminal at the top of the series circuit (in the same row of the resistor), and the other push-in terminal in the same row of the LED. Set the voltmeter to the 20 after =V . This setting will be kept for the rest of the lab since this setting will measure direct current. Measure the voltage of when the LED lights up. Record values in the proper Results table.

- Record the speed at which the magnets are spinning right before the diodes light up. You can take a photo of the oscilloscope with your cell phone for this step if you would like. Time how long it takes the LED to stop shining after you have stopped spinning the wheel.

Circuit Analysis Part 2 - Building a Parallel circuit

You will now build a parallel circuit

- This parallel circuit will be created on the 2nd half of the breadboard nearby the series circuit.
- Build the breadboard to look like the image below. A zoomed in photo of the parallel circuit is also provided.

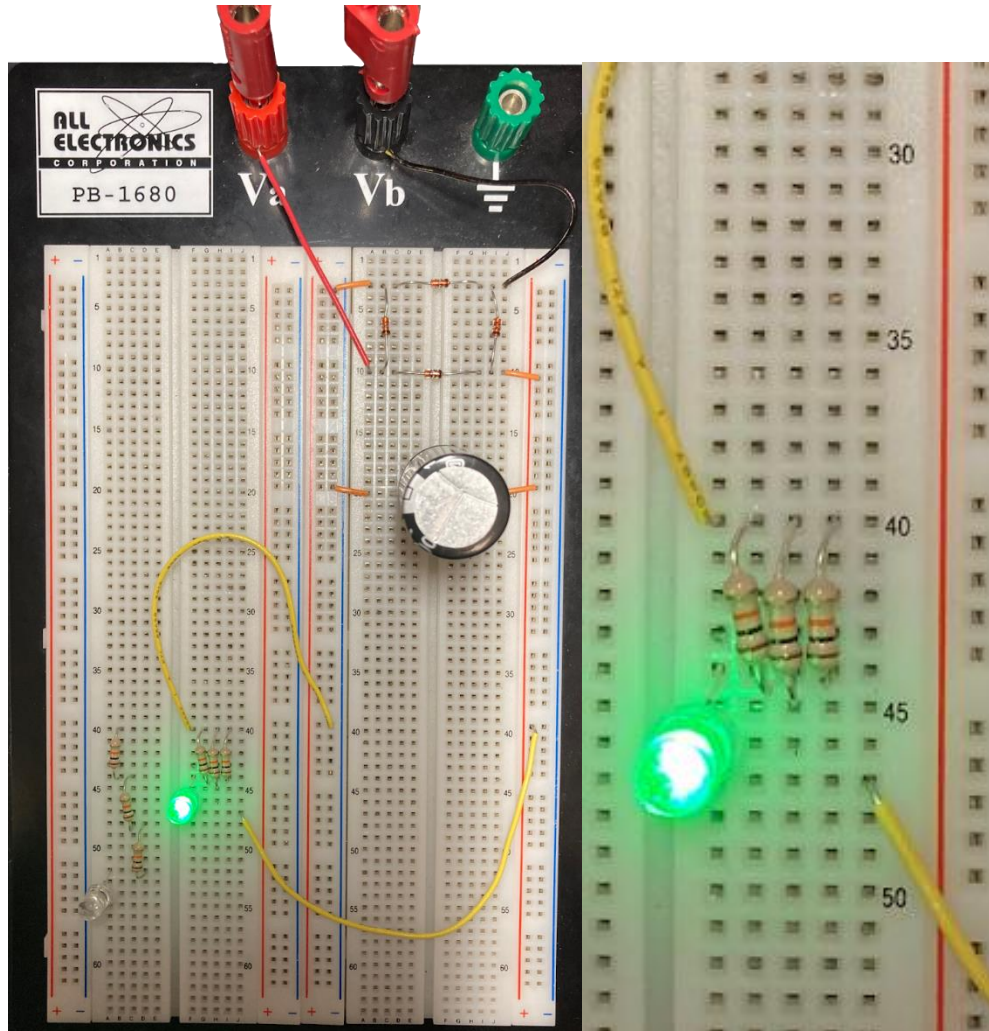


Figure 7: Full breadboard circuitry with zoomed in picture of a parallel circuit

- Spin the gear and watch as the LED lights up. Take note as you increase speed of the gear and the frequency of the lights.
- Use the voltmeter and the end clips, to clip to each of the push-in terminals. Set one push-in terminal at the top of the parallel circuit (in the same row as the three resistors), and the other push-in terminal in the same row as the LED. Measure the voltage of when the LED lights up. Record values in the proper Results table.
- Record the speed at which the gear is spinning right before the diodes light up. Time how long it takes the LED to stop shining after you have stopped spinning the wheel.

Results –
Observational Table I

	<u>Radius (cm)</u>	<u>Speed (revolutions / s)</u>	<u>Volts</u>
<u>Large</u>			
<u>Small</u>			

Energy and Speed Table Analysis Part I – II (all resistors are 10k Ohms)

	Energy Recorded (V)	Speed Recorded (Hz)	Time to dim after spinning stopped (s)
<u>Set-Up Part 1 – AC current</u>			-----
<u>Analysis Part I – Series Resistors</u>			
<u>Analysis Part II – Parallel Resistors</u>			

Conclusion

Throughout this experiment, several observations were made about gear ratios, conversion or energy and circuitry. This experiment was able to prove that smaller gears rotate faster than larger gears when spun at the same time. This experiment also showed the change from mechanical energy into electrical energy that was able to power circuits.

Discussion

How might scientists use these models to plan for real world applications, such as building cities or designing energy systems? How do you think these models could also be used in other energy experiments? What could the LED's represent in the real world?