Experiment 1 – Energy Conversion and Circuitry

Equipment -

- Voltmeter
- Breadboard with circuit kit
- Oscilloscope
- AC/DC Inverter Solenoid Apparatus with connector wires

Objectives-

1. To create AC current and convert to DC current using a bridge rectifier
2. To study loads with different equivalent resistance
3. To understand Ohm's Law and gear ratios

Investigation 1- Apparatus Set-Up

In this investigation the basic apparatus is set up. When the large turnstile is spun the magnets in the coil wrapped assembly will spin very rapidly. The energy produced is in the form of alternating (AC) current. By connecting the oscillosope to the Crank Wheel and the magnetic assembly, many observations can be made.

Procedure

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.

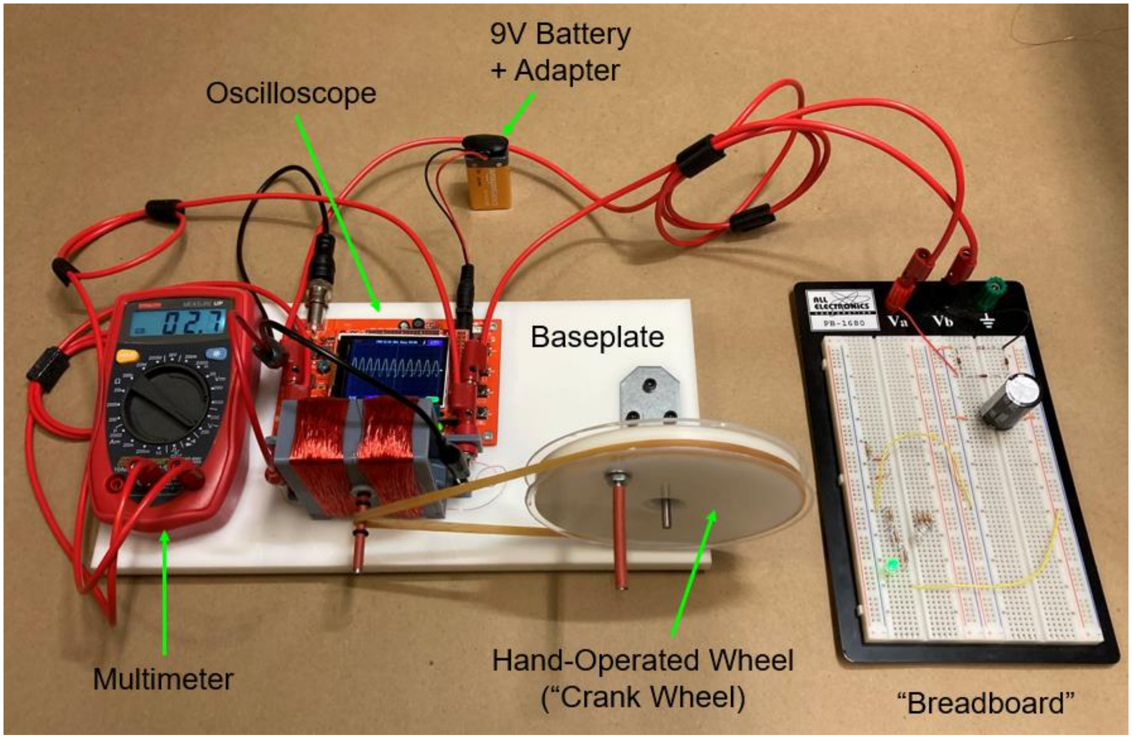

Figure 1. Full system assembly.

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.

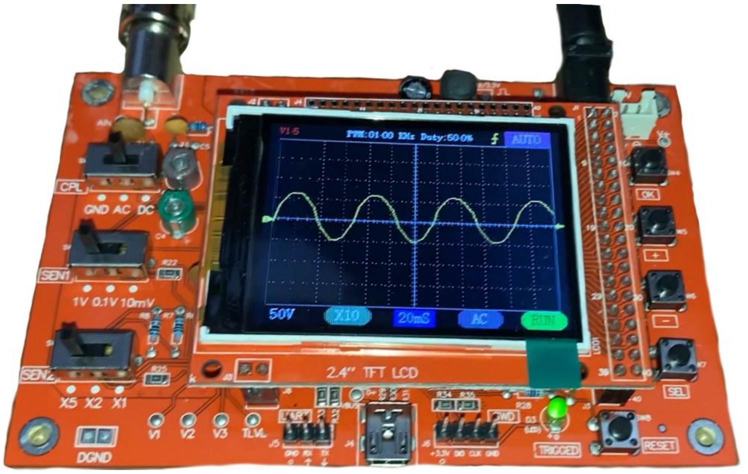

Figure 2. Oscilloscope measuring an alternating current signal.

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.

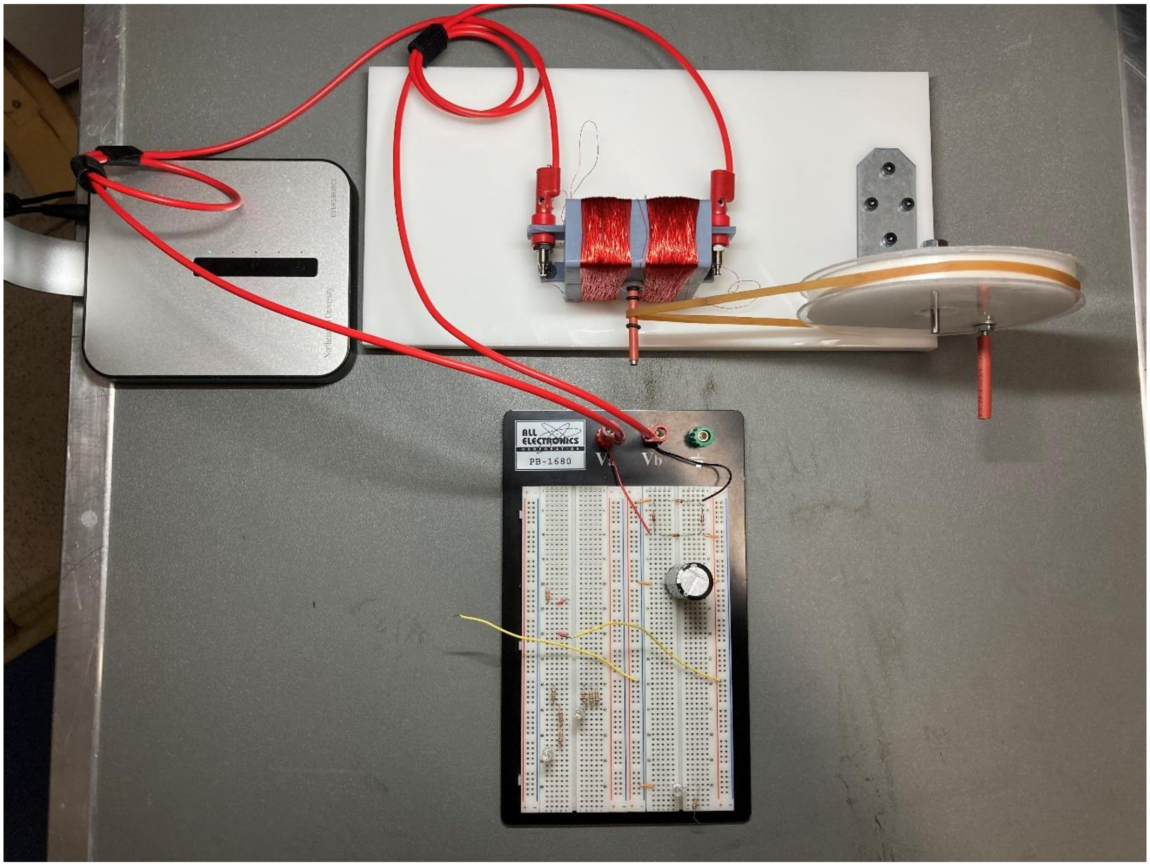

Figure 3. Connection of electrical generator to breadboard.

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

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. Record answer in Excel.

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.

   Note: The speed at which the smaller rotating mass—here, the shaft in the magnet container—spins is a direct consequence of the gear ratio. Gear ratio, in turn, results directly from the diameters of the two components that are attached by the driving mechanism, which in our case is the rubber band. Therefore, the larger the diameter of the large wheel (or the smaller the diameter of the small shaft), the greater the number of turns of the smaller rotating mass for every one turn of the larger rotating mass.

7. As you spin the gears, look at the oscilloscope. What shape does the line of the graph take?
   Note: On the oscilloscope the values at the bottom left and bottom middle. The bottom left shows the increment on the y-axis maximum (we use 5 V per dotted line). The bottom middle value shows you the x-axis total maximum (20 mS). This allows you to measure multiple facets of the system, including amplitude (distance of the line above the x-axis) and frequency.

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.

9. Pick three speeds at which to spin the crank wheel. As a suggestion, aim for approximately ¼ turn per second, ½ 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. Specifically, one sine wave is generated for every half rotation of the magnet system. Also, what do you notice about the amplitude as the frequency increases? Record numbers in an Excel spreadsheet.

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 (1 second / 50 milliseconds) = 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:

$$Rotational\ speed\ \left(\frac{rev}{s}\right) = (\#\ of\ sine\ waves\ ) \times 10 \qquad (1)$$

11. You can use the information you just recorded above to verify 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 of the magnet pair by the inverse of the gear ratio to get the *actual* rotational speed of your large wheel:

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

(2)

Investigation 2- Series Circuit

In this investigation the breadboard componenets will be tested. The investigation involves constructing the bridge rectifier. A bridge rectifier will convert the mechanical energy from the gear into usable electrical energy. The second half of this investigation will be builindg a series circuit will an LED. This LED offers a qualitative approach to check qualitative data.

Procedure

1. The bridge rectifier consists of 4 diodes in a square shape. These diodes have black stripes on one end, where electricity cannot enter through the black-stripe end.

   Follow the diagram below to build the bridge rectifier exactly as shown. 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. If time, draw out a schematic of the bridge recitifer.

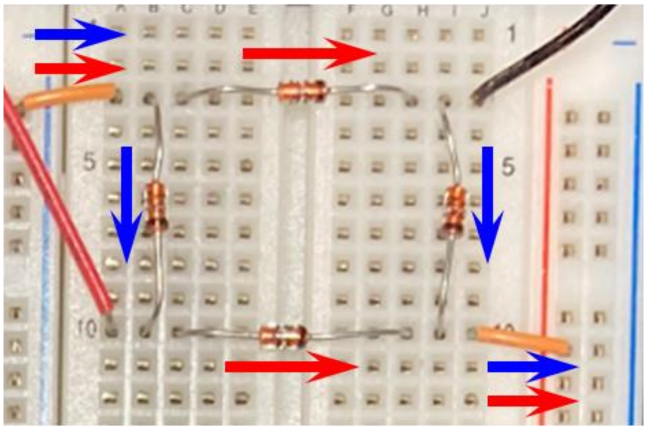

Figure 4: Bridge rectifier

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

3. 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. The shorter leg is therefore “flat” while the longer side is bent. A common phrase with electronics is that “flat goes to ground,” so connect the capacitor such that the flat side goes to the ground/negative side of the breadboard terminals).

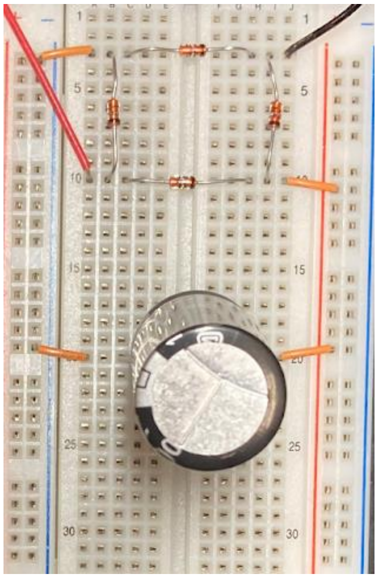

Figure 5: Power source plus bridge rectifier circuitry

4. This is the energy source for your circuits throughout the rest of the lab. Connect the oscilloscope to the capacitor. 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?

You will now build your first simple circuit.

5. The two long yellow jumper cables will be used to provide power to your series circuit. Three resistors will be needed for each circuit. Each resistor has a resistance of 100 Ω. Calculate the equivalent resistance for the series circuit.

$$Req = R1 + R2 + R3 \quad (3)$$

6. 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.

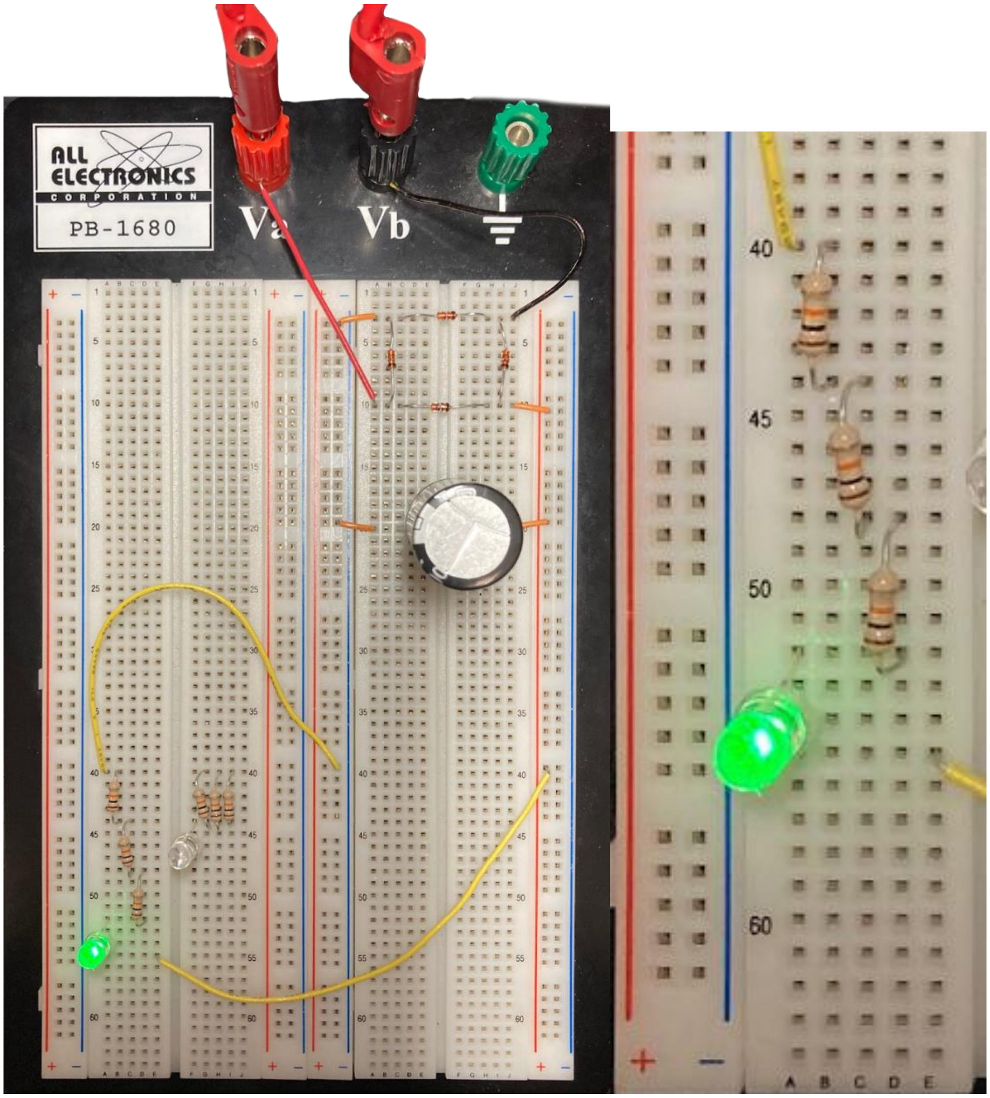

Figure 6: Full breadboard circuitry with zoomed in picture of a series circuit

7. 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.
8. 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 series circuit (common to the resistor), and the other push-in terminal common to 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. Do this in three trials to get an average voltage reading. Record values in Excel.
9. Calculate the current through the system using Ohm's Law.

$$R = \frac{\triangle V}{I} \ (4)$$

Calculate the power delivered to the LED using the following equation.

$$P = \frac{\triangle V^2}{R} = I^2 R \ (5)$$

10. 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.
11. For this part, we'll assume the capacitor is fully charged. The capacitor will be discharged by disconnecting the AC power source at the Va and Vb inputs. Predict how long it will take for the

capacitor to fully discharge in the system, or how long the LED will be lit, using the following equation.

$$I(t) = \frac{V_0}{R} e^{-\frac{t}{RC}} \quad (6)$$

Use the current you found in Step 5 for your calculations.

12. Spin the wheel so that the capacitor is close to fully charged. Now disconnect the AC power source through the two leads at the Va and Vb inputs. Time how long it takes the LED to stop shining after you have stopped spinning the wheel. Compare this time to the time calculated in Step 7. Do the results match? What could be a source of error?

Investigation 3 - Parallel Circuit

You will now build a parallel circuit.

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

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

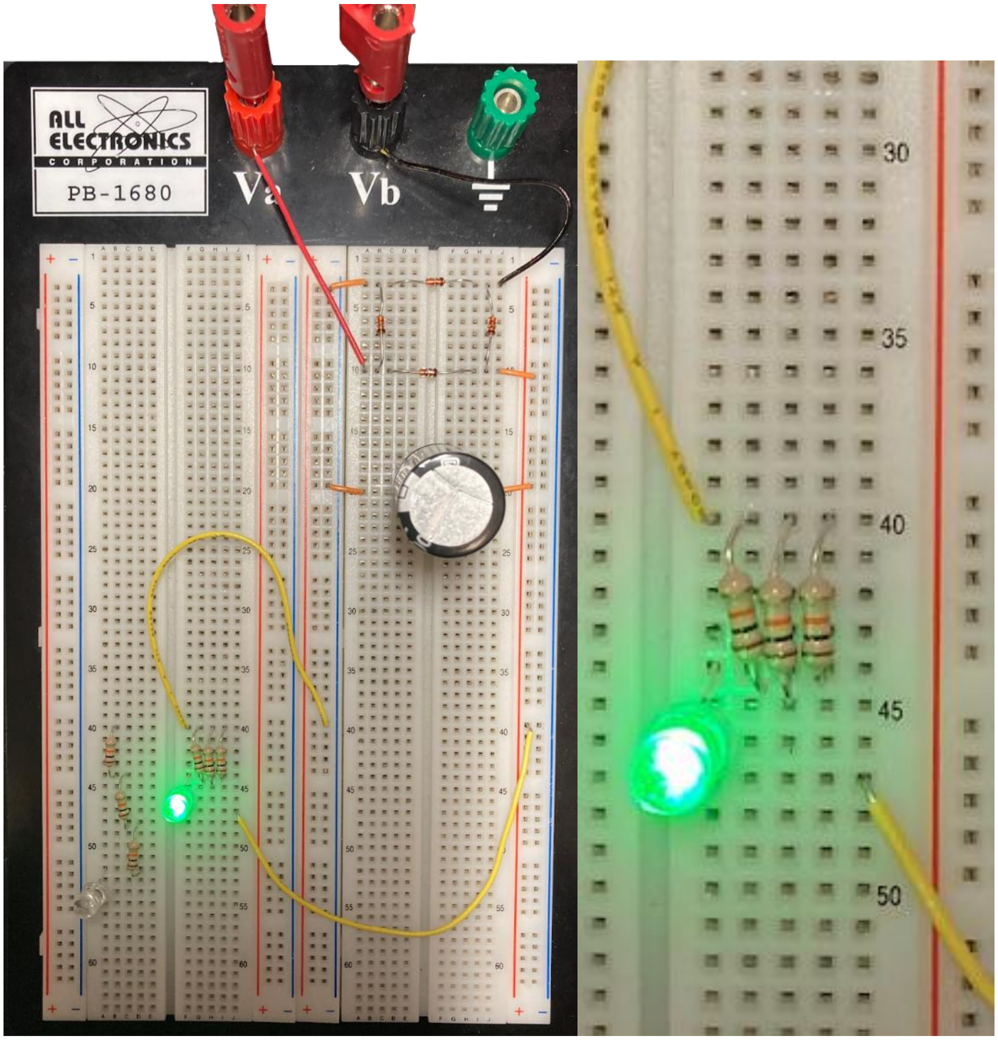

Figure 7: Full breadboard circuitry with zoomed in picture of a parallel circuit

3. 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.
4. 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 (common to the three resistors), and the other push-in terminal common to the LED. Measure the voltage of when the LED lights up.
5. Calculate the current through the system using Equation 4. Calculate the power delivered to the LED using Equation 5.
6. 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.
7. For this part, we'll assume the capacitor is fully charged. The capacitor will be discharged by disconnecting the AC power source at the Va and Vb inputs. Predict how long it will take for the capacitor to fully discharge in the system, or how long the LED will be lit, using Equation 6. Use the current you found in Step 5 for your calculations.
8. Spin the wheel so that the capacitor is close to fully charged. Now disconnect the AC power source through the two leads at the Va and Vb inputs. Time how long it takes the LED to stop shining after you have stopped spinning the wheel. Compare this time to the time calculated in Step 7. Do the results match? What could be a source of error?

Questions