1 Objective

Explore the operation of AC and DC generators, and measure the output from the device operated as a generator. Then run the device in the DC motor mode and measure the net voltage going into the armature during operation, exposing the phenomena of back voltage.

NOTE: Please take care of our motors. They are old, but they are of fine quality and can’t be replaced.
2 Theory

It would be hard to overstate the impact of Faraday’s law of electromagnetic induction. It has quite literally lifted humans to another entire level of sophistication, and changed us forever. Using Faraday’s law of induction, it became possible to convert mechanical energy into electricity, then ship that energy hundreds of miles away to be used somewhere else. We convert the mechanical energy to electrical energy through induction, then use that energy very often by taking advantage of the torque on a current loop in a magnetic field. Without being able to move energy around like this, we would still be traveling the continent by steam engine. This lab explores the motor and the generator, which happen to be one and the same mechanical device.

Equation 1 is the law as we have learned in class. In this law, magnetic flux is calculated as described in equation 2.

\[ \varepsilon_{mf} = -N \frac{d\Phi_B}{dt} = -N \frac{d}{dt}(BA\cos(\omega t)) \]  

\[ \Phi_B = \int \vec{B} \cdot d\vec{A} \]  

The \( \varepsilon_{mf} \) can be generated by changing anything in the magnetic flux term. That is, we can change the B field, the area of the loops or the angle between the area vector and the B vector. In the case
of a generator, clearly the rotation of the angle between the vectors does the job for us. Taking the
derivative of eq. 1 then gives us the generator equation, eq. 3.

$$\varepsilon mf = NBA\omega \sin(\omega t)$$  \hspace{1cm} (3)

3 Procedure

The basic equipment for this experiment is as follows:

1. Induction motor/ generator
2. Labquest DAQ with differential voltage probe
3. Generator VI
4. Motor VI
5. Computer running LabVIEW
6. 2- DC power supplies
7. Multimeter

3.1 Generating AC and DC voltage

In this part of the lab we will create a constant magnetic field in the field coil, and then turn the crank
on the armature and generate voltage. Depending on where the brushes are, we will either generate
AC or DC voltage from the armature. Our goal is to first record this data as we turn the crank, and
then collect enough data to make some estimate of NBA as given in eq. 3. The outline which follows
is intended to help you complete these goals.

1. Hook up the field coil to a Mastech DC supply. You should run 4.0 amps through the coil as
   read from the front panel of the supply. We will power the field coil with this supply and we
   will not use the Mastech supply for any other purpose during the lab. While this is not how
   motors are run in the real world, it will simplify our lab by making B-field constant throughout
   the experiment.
2. Arrange the two brushes to the outside commutator rings so as to generate an AC voltage from
   the device.
3. Open the LabVIEW virtual instrument (VI) called GeneratorRecord.vi. The VI will record the
data to a file if the save data switch is on.
4 Hook up the Vernier differential voltage probe the the terminals connected to the generator brushes
5 Set the time you wish to record data on the VI front panel. (10 to 20 seconds)
6 Run the vi, and turn the crank on the generator. Save the output file which can be opened in Excel for data analysis.
7 Run the vi multiple times recording to the best of your ability signals at various generator RPM rates.
8 Rock the crank arm at different armature positions. Seek out where it produces the largest effect, and where it produces the smallest effect.
9 Analyze the data to establish a trend in the generator output. Record and measure as many different rotation speeds as possible.
10 Now analyze the data for peak voltage at a specific frequencies.
11 Plot the values you mine from the data on a plot of $\varepsilon m f$ verses $\omega$. The slope of this line will be NBA in eq. 3. Obviously the larger your range of frequencies, the better the estimate of NBA will be.
12 Repeat the process of recording the generator output for the DC mode. This is simply done by moving the brushes to the split ring commutator.
13 Record DC data when the generator crank is turned forward, then backwards.
14 These data plots should be in your lab report.
15 You can try to analyze the data for NBA if you have time.
3.2 Measuring back $\varepsilon m f$ in a DC motor

In this part of the lab we will send a DC voltage into the armature coil so as to run the device as a DC motor. Our goal is to record the voltage drop across the coil while the motor is running. This voltage drop will be close to the constant voltage being pushed by the supply minus the back voltage be generated by the turning coil. We’ll measure this back voltage and compare it to the predicted voltage using the NBA value determined in part 1. The following outline are suggested steps to help you get and analyze the data.

1. Measure the resistance of armature coil. You will need to turn the crank slowly and record many resistance values. Then take the average resistance.
2. Measure the exact resistance of the $1 - \Omega$ power resistor using the multimeter. Note that with this resistance in series with the armature, the two resistances will act like a voltage divider.
3. Derive a formula for determining the voltage drop across the armature given a measured voltage drop across the power resistor.
4. Move the brushes to the split ring commutator, if they are not already there.
5. Hook up the differential voltage probe across the power resistor, NOT ACROSS THE AR- MATURE. This is the voltage probe hooked up to the Vernier Data Acquisition DAQ unit.
6 Open the DC Motor VI in Labview. It may be necessary to unplug the USB cable to get the Labquest DAQ to wake up.

7 Use the second power supply to send a DC current through the armature coils. It is important to put a $1 \Omega$ power resistor in series with the coil as shown in the figure. We will measure the voltage output across this resistor rather than measuring the armature directly because the voltmeter does not have a large enough range to measure directly. It will help if you nudge the motor to get it going. **NOTE: the power resistor will get hot. Be careful.**

8 run the VI while the motor is running and record the output voltage pattern.

9 Now, to get a base line on the input voltage, turn the field coil current off and record an addition data set with the armature at rest but using the same input voltage as when the motor was running. Be sure the brushes are on separate rings of the commutator and not being shorted out. This is usually when the armature coils are horizontal.

### 4 Things to include in your report

For full Credit on your report, be sure to include the following components.

1 Plot of the AC generator data
2 Data table for angular frequency and output voltage.
3 Graph of data and best fit line estimating NBA
4 Plot of the DC generator data
5 Plot of the DC generator data for the crank turning in reverse
6 Data for measured resistance values in the DC motor part of the lab.
7 Plot of the back voltage for the DC generator
8 Estimate of the back voltage compared to the measured back voltage.