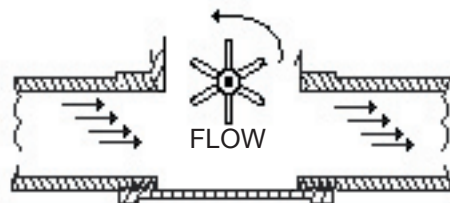


## Note to the Teacher

Please note: this lesson contains most of the same materials, and has the same lab procedure as the lesson “How Much Current Can a Robot Draw?” However, it is designed for a somewhat different purpose: to continue the lessons in circuits that began with the Ohm’s and Kirchhoff’s Law lessons. We think that the focus is different enough to justify a different lesson page. But please be careful not to confuse this lesson with “How Much Current Can a Robot Draw?” because there are a number of important differences: above all, this lesson is more concerned with theory.

### Current Flow

Mechanical engineers are concerned about the flow of a liquid in a pipe. Sometimes they have to measure the flow rate of the liquid. The units for the flow rate are given in volume per unit time, such as gallons per minute or liters per second. A device called a paddle wheel flow meter measures the flow rate and is shown below. When a liquid flows in the pipe the paddle wheel rotates and one of the blades of the paddle wheel alerts an electronic sensor that sends an electronic pulse to a circuit that calculates the frequency, or the number of pulses per second. Once the frequency can be determined the flow rate can be calculated. The important issue here is that in order to install the meter, an intervention has to take place. The pipe had to be cut, the flow meter inserted, and the pipe reattached to the meter. The liquid flow is also called a current flow. Mechanical engineers use the symbol  $Q$ , to symbolize the flow rate.



An electric current flow takes place much in the same manner as fluid flow in a pipe. Electric current flows when charged particles flow through a wire or any conductor of electricity. The definition of current is:

$$I = q/t$$

Eq 3

Where  $q$ , the charged particle moving in the wire, is measured in Coulombs and  $T$  is time, in seconds, that it takes to move the charged particle and  $I$  can be expressed either in the units of amperes (amps) or coulombs per second. One ampere is the equivalent of one Coulomb per second.

Figure 8 illustrates the method that schematic diagrams represent current flow. Figure 8a shows the current flowing toward the right with a value of 3 amps while figure 8b shows the same current flowing toward the left with a value of -3 amps. Both schematics are correct. Any time a current is shown with a negative value, the direction can be reversed and the value replaced with a positive value. Likewise, any time a current is shown with a positive value, the direction can be reversed and the value replaced with a negative value.

## Note to the Teacher

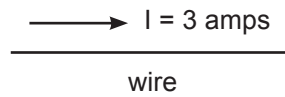


Figure 8a

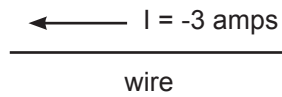


Figure 8b

Suppose that in equation 3,  $q$  represents an electron, whose charge is commonly expressed as  $-e$  because an electron is negatively charged. Now equation 3 becomes:

$$I = -e/T$$

Eq 4

Figure 9 illustrates the difference between electron current flow and conventional current flow. In figure 9a we have electrons moving in a wire toward the left and the result is called electron current flow. Because electrons are negatively charged and the current has a negative value, we can also say that conventional current flow is toward the right as shown in figure 9b.

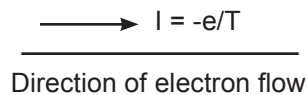


Figure 9a

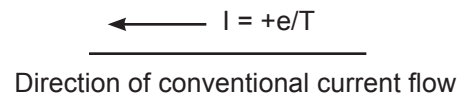


Figure 9b

### Example problem Number 1

If  $8 \times 10^{-8}$  Coulombs flow through a wire in 2 microseconds, determine the  $I$ , the current flow.

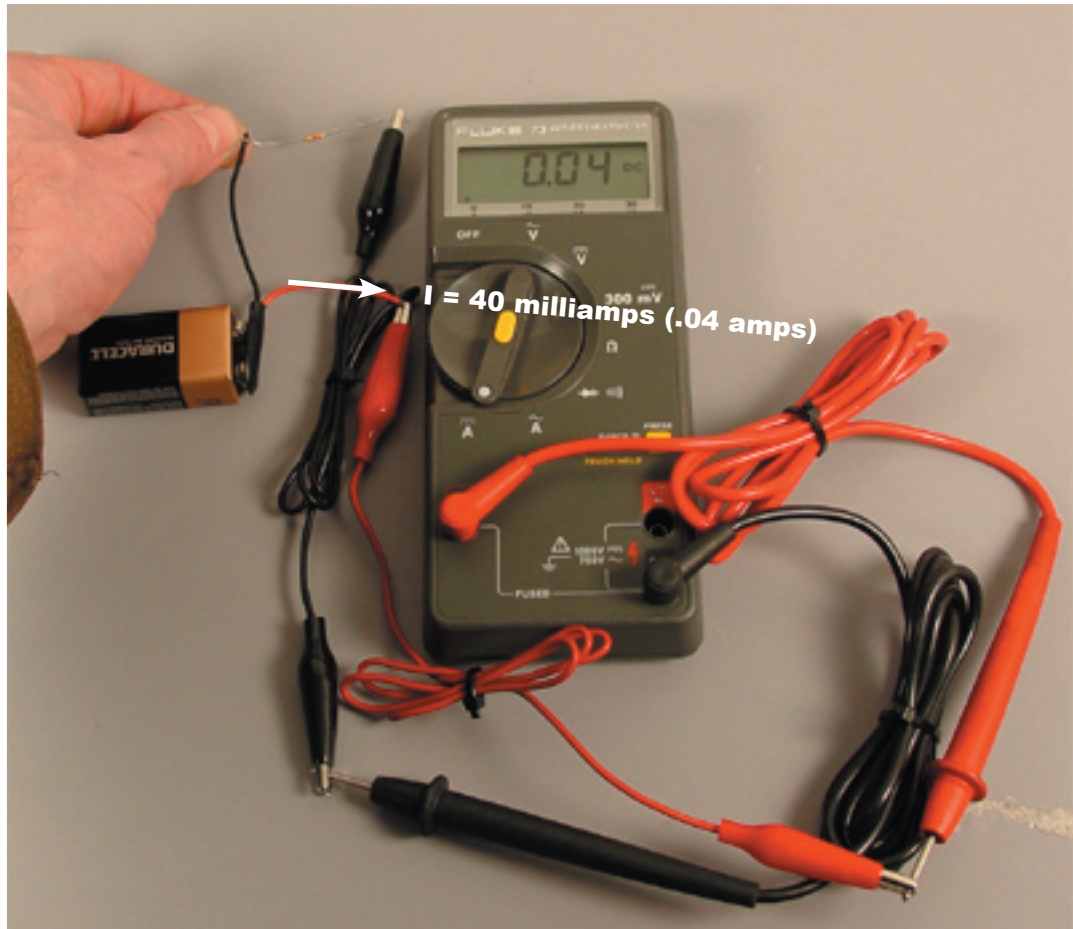
Solution:

Using Equation 3, we have:

$$I = q/T = 8 \times 10^{-8} \text{ amperes} = 4 \times 10^{-2} \text{ amperes} = 40 \text{ ma}$$

A special meter that has been designed to measure the electric current is called an ammeter. An ammeter is one of the functions of a multimeter. It has two terminals that a red lead and a black lead are to be connected. The red lead is connected to the A terminal of the meter and the black lead is connected to the COM terminal of the meter. Note that just like the paddle wheel flow meter, the wire in the ammeter circuit has to be cut, and then attached to the meter, as shown in the picture on the following page.

## Note to the Teacher



### Overview of the Investigation

In this investigation, students will learn the relationship between the amount of work the robot is doing and the amount of current it draws while doing it. Students will use the Vex Robotics System in a laboratory setting and conduct scientific inquiry-based experiments to determine the effect that traveling increasing grades has on current draw. Students will wire a multimeter in series with a battery that is powering the robot. They will then take readings of the multimeter as the robot negotiates grades increasing in 5 degree increments from 0- 25 degrees. After completing the experimental procedure, they will chart and analyze their data.

We do not recommend managing a classroom while multiple investigations are being done using multiple Vex systems but only one crystal frequency. If you have questions on this topic, refer to: Inventors Guide Unit Six (page 21)—Control and Appendix E—Control Configuration (page 11-18) Our recommendation is to purchase additional crystal sets from Vex (see Unit 6 page 22 in the Inventors Guide.)

### On Lesson Completion, Students Will Be Able to

1. Apply the scientific process
2. Modify a battery, placing it in series with a multimeter

## Note to the Teacher

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3. Measure current output while the robot climbs inclines at increasing angles
4. Collect data from their investigation
5. Apply and describe the various points of experimental procedure:
  - a. Experimental hypothesis
  - b. Measurement technique
  - c. Multiple trials
  - d. Systematic Error
  - e. Random Error
6. Write a summary describing what they learned in the investigation

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### Description of the Investigation

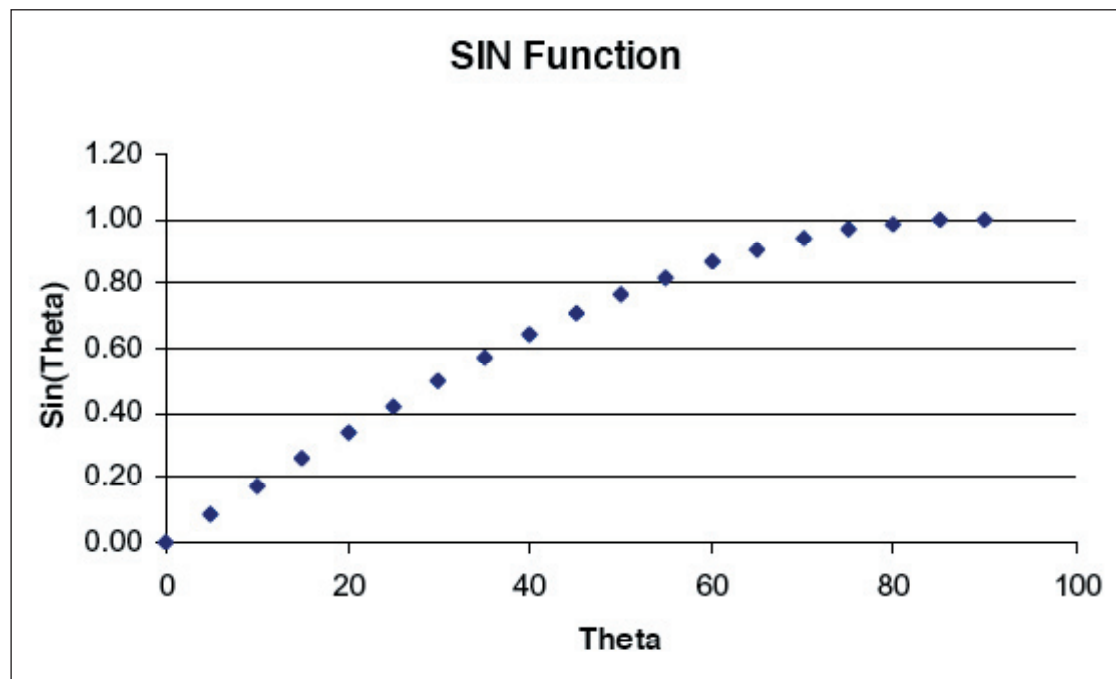
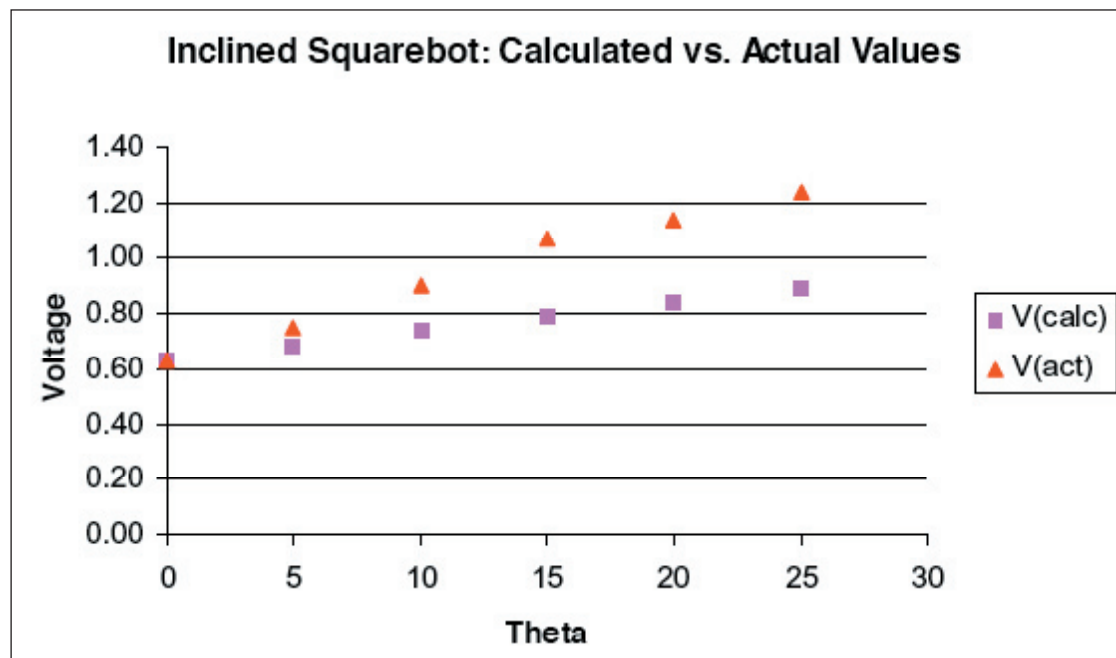
To begin this investigation, students, working in teams of 2 or 3, will connect a battery in series with a multimeter. Once the multimeter and battery are in series, the students will attach the two to the robot and begin monitoring current output. The students will then use the remote control to move the robot along planes of increasing incline while measuring the system's current draw. The first measurement will be taken at as the robot drives along a flat plane. In succeeding trials, the students will measure current draw as the angle of elevation is raised in 5° increments. The final trial will be run at an incline of 25° to the horizontal.

Once they have finished the experimental procedure, the students will review and evaluate their data. There are examples of graphical analysis in the resources section of the lesson.

The hypothesis is that the current draw is a function of the amount of work done by the robot. The work done by the robot will increase as the steepness of its path increases, so it can also be hypothesized that the current draw is a function of the incline of the path traveled by the robot.

**See helper pages on Current and Voltage.**

## Note to the Teacher



### Materials Needed

1. Vex kit/Programming kit
2. Multimeter
3. Wires with connecting leads
4. 7.2 Volt battery
5. Wire cutters

## Note to the Teacher

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6. Alligator clip or female spade connector
7. Wire strippers
8. Crimper or pliers
9. Electrical tape
10. Wooden board (8'x 12" x 0.5")
11. Protractor

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### Math Versus Science

As students complete the investigations, they will begin to understand the relationship between mathematics and science. Mathematics is pure; when you plug numbers into equations, you will get the same result every time. Science, on the other hand, is dependent on multiple variables that may or may not be in control of the investigator. A good scientist will eliminate as many uncontrollable variables as possible so that they are able to analyze and measure the results of their investigation.

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### Experimental Error

There are many things that can cause your experimentally measured numbers to fall off-target from the predicted values. Here are a few:

- **Systematic error** is something in the experiment that always throws off the data in the exact same way. Some examples of systematic errors are a dead battery, improperly connected components, or a defective motor.
- **Random error** is caused by small factors that constantly change and affect the experimental results. In this experiment, random error may be caused by inconsistent starting points, imprecise measuring procedures, or a fluctuating battery level.

There are many things that can cause your experimentally measured numbers to fall off-target from the predicted values. Here are a few:

- Clutch Slippage: At higher torque, the clutch slips to reduce the chance of damage to the motor. This results in a shorter distance being traveled.
- Motor temperature
- Friction
- Battery power varies due to charge level

This investigation includes worksheets where students can capture data and write conclusions.

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### Helpful Hints

1. If the students have access to a multimeter similar to the one in the videos, it will be easier for them to follow the video instructions. If the students are using a different multimeter, show them how to use it to measure current draw.
2. Watch the video labeled "Current Draw: Lesson Set up" for instructions on connecting the battery and multimeter in series. Remember that this modification only needs to be done to one battery! This is the preferred way to set up the meter; other methods may blow a fuse or produce inaccurate readings.
3. If the robot is not responding to the remote control, try the following steps. First, open easyC and download the default code to the robot. If that doesn't work,

## Note to the Teacher

check the crystal frequency on the back of the remote control. And make sure that it matches the frequency in the receiver. Finally, make sure the left motor is plugged into port 3 and the right motor is plugged into port 2.

4. It is recommended to have at least 3 students in a group for this activity: one to run the transmitter, one to record the readings, and one to handle the robot.
5. Work at floor level—robots can fall and break!
6. Use Microsoft Excel to graph the results. Students should graph current as a function of the angle of elevation.

### How to Use the Lesson Materials

1. Review the other lesson materials thoroughly.
2. Read the remainder of this document. It will serve as a general guide for how to teach the lesson content.
3. Have your students review the Introduction for Students, under Guide. It contains the same material as the beginning of this document, and focusses on providing a working understanding of current. Under “Helper Link,” “Current,” “Voltage” and “Resistance” provide information on fundamental physical concepts. Under “Resources,” the Multimeter Guide and the Crimping Guide provide detailed instructions on using tools essential to the completion of the experimental procedure. Additionally, “Current Worksheet (xls)”, an Excel file, provides a set of sample values resulting from the experiment. Note that there is also a printable pdf version of this worksheet called “Current Worksheet (pdf)”. You should choose whether to print and hand out the pdf document and ask students to complete the table by hand, and then use the data to draw their own graphs, or to tell students to save the Excel file to their own computer, and modify the document by adding data gathered from their own experiments. Lack of computers and potential technical problems may make using the pdf version the easier option. On the other hand, if you open the Excel document, you will see it enables various graphical analyses in ways the pdf version does not. In addition, many if not most professional employment positions require some familiarity with Excel, so providing students with experience in Excel is desirable if possible.
5. Modify and add to the lesson in the way that will best serve your classroom.
6. Teach the lesson, drawing on lesson materials where appropriate. The Ohm Lesson Procedures document asks students to perform a simple experiment where they measure voltages, resistances and amperages from simple circuits with fixed resistors to demonstrate Ohm’s Law.
7. Assign the “Checking for Understanding” Quiz/Worksheet.