Note to Teacher

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.)

Students will be able to:

1. Apply the scientific process

2. Modify a battery, placing it in series with a multimeter

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

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 5º increments. The final trial will be run at an incline of 25º 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 Teacher

Math versus Science

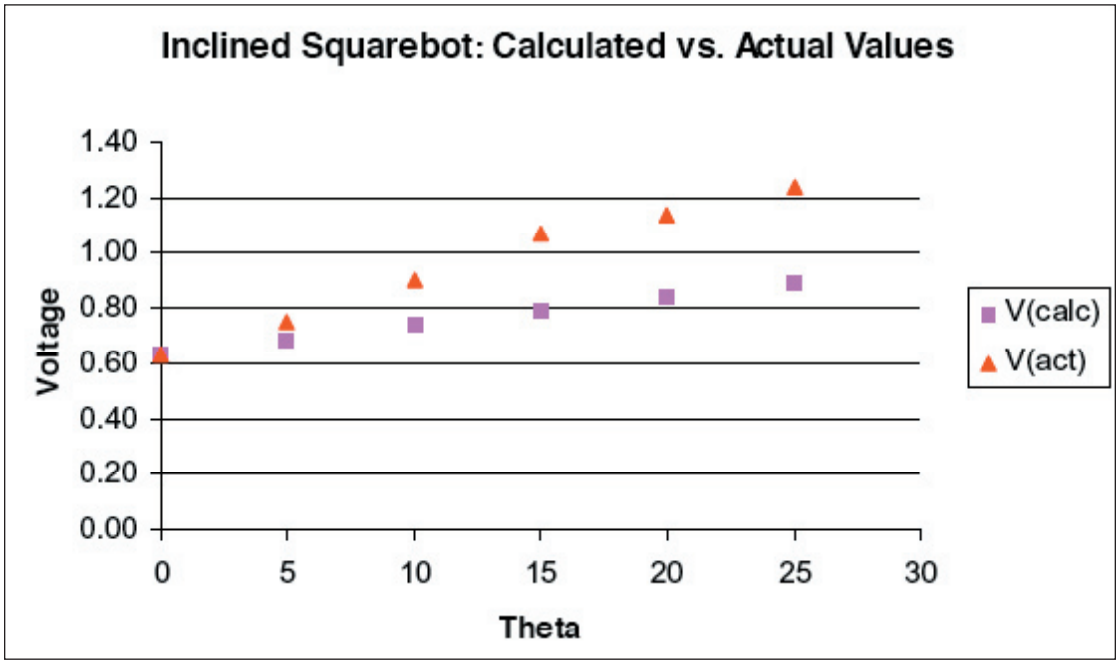
As students complete the investigations, they will begin to understand the relationship between mathematics and science. Mathematics is pure; when you plug numbers into equations, you will get the same result every time. Science, on the other hand, is dependent on multiple variables that may or may not 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.

Experimental Error

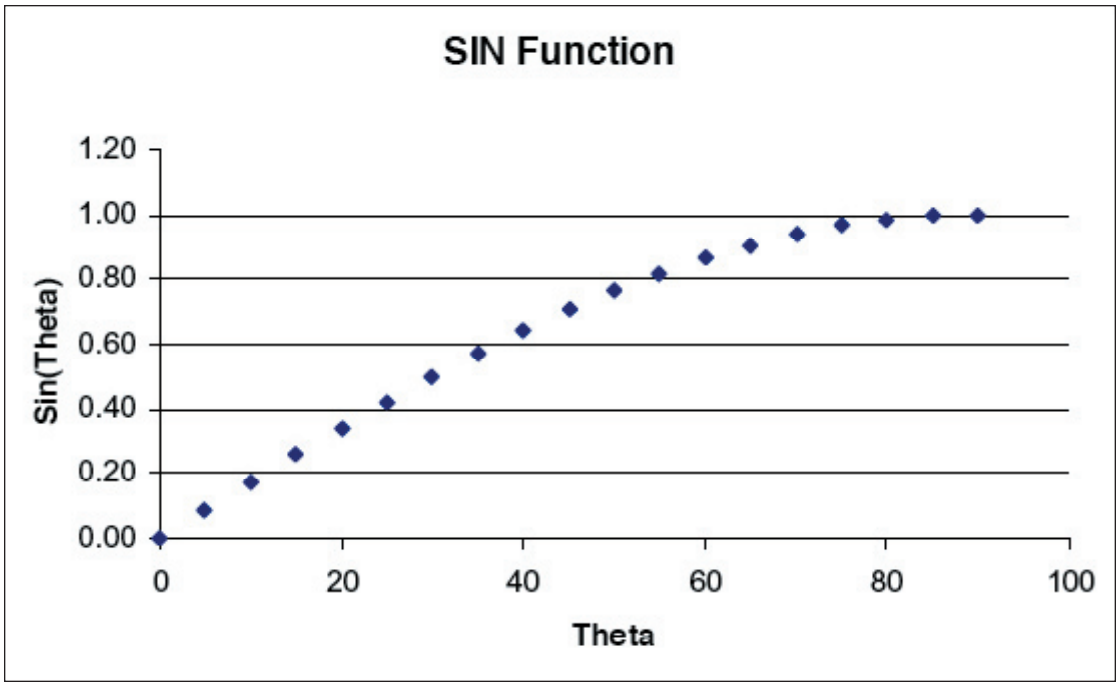
There are many things that can cause your experimentally measured numbers to fall off-target from the predicted values. Here are a few:

- **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.

This investigation includes worksheets where students can capture data and write conclusions. The figures below are examples of graphical analysis of the data in Microsoft Excel.



Note to Teacher



Materials Needed

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

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, 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.

Note to Teacher

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 "Overview/PowerPoint/Lesson Guide." It will serve as a general guide for the lesson content. It is also modifiable, but note that it is only modifiable if you use the "Save As" option or browse to it. (If you click on it in the lesson page, you will not be able to modify it.) To get a version you can modify, go to "File/Save As" to save a copy to your computer, or browse to Vex Curriculum/Content/Lessons/current/mult/Current.ppt on the Vex curriculum, and copy it to your computer.
3. Read the remainder of this document. It will serve as a general guide for how to teach the lesson content.
4. Have your students review all the materials in "Background." Under "Helper Link," "Current" and "Voltage" 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 postions 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. You may wish to begin the lesson by having your students go through Introduction for Students and the PowerPoint Lesson Guide, as these link an explanation of basic electrical principles to the lesson procedures.
7. Assign the "Checking for Understanding" Quiz.