Note to the Teacher

When students compete in robotic competitions they often have to make decisions on which motor to use for what application. This lesson begins to introduce students to some of the features of electronic motors.

Things the robotic designer needs to know:

- How much will the motor lift?
- How fast will the motor lift?
- How can I control the motor's speed and the strength (there are tradeoffs)?
- How much current will the motor draw?
- What causes my motor to burn up?

Please note

If you have ever downloaded ROBOTC firmware (or programs), you will now have to download a ROBOTC sample program, "Dual Joystick Control." Alternately, you can re-download the Vex Default Firmware.

- Select File/Open Sample Program
- Browse to Radio Control Transmitter/Dual Joystick Control and download it.
- Turn the robot on and off. The robot should now work with the remote control as it did out of the box.

Note that if you have never downloaded anything onto your VEX microcontroller, you can skip this step.

VEX Kits and Accessories Needed

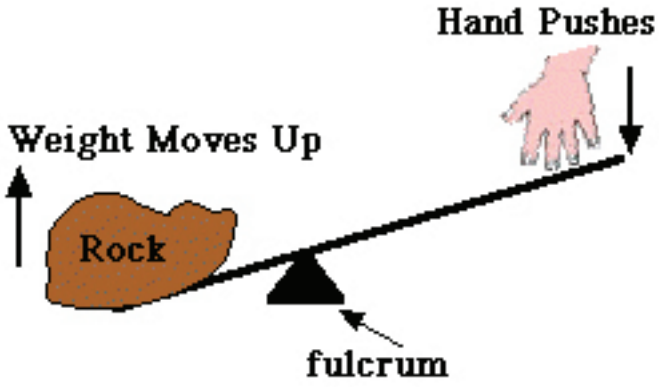
1. VEX Protobot Kit
2. Hardware and Metal Kit
3. Transmitter & Receiver Kit
4. VEX Microcontroller
5. Limit Switch

Additional Materials Needed

1. Weights of your choice (Please note: you can use whatever lifting device and weights are most convenient. The only constraints are that the lifting device should not weigh more than 5 ounces, that it should be able to hold 15 ounces of additional weight, and that the weights used are fairly small and equal to each other, like washers or pennies.)

Investigation Description

In this investigation students will learn one way to measure stall torque for the VEX motors. They will learn about the VEX clutch. In the ideal test system the experimenter would be able to count on the slip-clutch to disengage before the motor was damaged. In our investigation we found that the slip-clutch disengaged after the motor had already reached its limit. In other words, the motor would



Note to the Teacher

be damaged with the slip-clutches that we experimented with. This is important for you to note to your students. It is important, therefore, to stress that the motor should be run for 1-2 seconds maximum.

We will be measuring the amount of rotational torque the motor is able to lift before it stalls. This will be accomplished by building a test bed that enables the experimenter to vary the amount of weight the motor is able to lift. Students will also learn a lesson about leverage; the further the weight moves from the fulcrum the larger the rotational torque.

Extension activities:

Challenge students to determine the distance and amount of force that must be applied in order to lift a specific amount of weight.

The design of the testbed will make the arm depress a limit switch when it is raised. A programming challenge would be to write a program that would make this limit switch stop the motor.

Use research to identify and define other key terms used in the lesson.

Definitions:

ful•crum

n. pl. ful•crums or ful•cra (-kr)

1. The point or support on which a lever pivots.

2. An anatomical structure that acts as a hinge or a point of support.

At the End of the Lesson, Students Will be Able to:

1. Construct the test bed that allows the investigator to test motor stall torque.

2. Apply and clarify various points of an experimental procedure:

- Experimental hypothesis
- Measurement technique
- Multiple trials
- Systematic error
- Random error

3. Collect data from the investigation

4. Graph results

5. Calculate averages

6. Measure accurately using a ruler/meter stick or tape.

7. Measure accurately using a scale or student developed measuring device in ounces and grams.

8. Convert between various units of measure.

9. Write a conclusion that summarizes the lessons learned in the investigation.

Description of the Investigation

In this investigation students will:

- Discuss the importance of selecting appropriate motors
- Identify key terms in the unit
- Apply scientific process

Note to the Teacher

- Build a test bed
- Move a weight along the lever enabling them to test specific conditions
- Calculate TORQUE = distance times weight (D x W = TORQUE)
- Run their investigation at least three times with each condition
- Accurately measure the results in each condition and record it
- Convert mass to metric units
- Learn the relationship of weight to distance from the fulcrum
- Describe torque in terms relating to weight times distance
- Write a conclusion describing what they learned

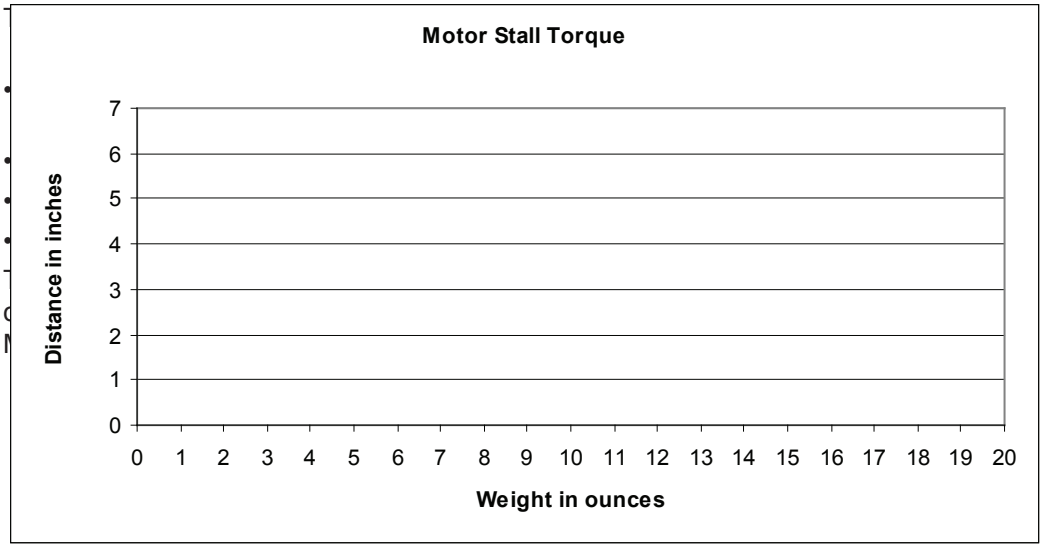
Math Versus Science

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.



Note to the Teacher

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/stall_torque/Stall_Torque.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. Run the experiment yourself, to be sure that everything will work in the classroom.
4. Have your students review all the materials in "Background." Under "Helper Link," "Factor Label Method" will provide help converting inch-ounces to foot-pounds and Newtons. "Lever Law" will explain the principal of the lesson, and "Clutches" will explain how clutches in general, and the Vex clutch in particular, help to protect the motor. Under "Resources," "Stall Torque Construction Slide Show" provides step-by-step instruction on how to build the platform needed for this lesson. Additionally, "Stall Torque 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 "Stall Torque 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. Note that you have a choice, under Lesson, between an interactive flash slide show, and a pdf version covering the identical material. Many teachers will want to print out the pdf version so that students have an easily accessible guide while they are going through the lesson.
7. Assign the "Checking for Understanding" Quiz.