Objective

Students will be able to:

- Understand the Matlab interface
- Write basic commands in the command window
- Write basic functions in editor window

- Describe force and spring constants
- Design an experiment to determine the spring constant of a spring
- Use the results of the experiment to make a model and make predictions

Prerequisites:

- Students need to know how to type
- Students need to know what coding is
- Students need to understand equations with 3 variables
- Students need to understand force and distance

Key points

- Matlab is a computer program that performs sophisticated calculations
  - The user can type commands, and the computer will do them
    - But! The user must use the computer's language
  - The user can tell computer to do many things in a row, and give 1 answer
    - The user can turn a piece of code into a function

- Force is a push or a pull on an object
  - Like gravity, or pushing desk, etc.
- Springs can apply a force too
  - When you push on them, they push back
  - When you pull on them, they pull back
  - THE HARDER YOU PUSH/PULL, THE HARDER THEY PUSH/PULL BACK

Assessment

1. If a spring has a spring constant of 20 and is stretched 0.1 meters, what is the force?

2. If you hang 1 N of force from a spring that has a spring constant of 100, how far will it stretch?

3. Draw a graph of these data:

distance (meters)	force (Newtons)
0.005	0.05
0.012	0.1
0.021	0.2
0.050	0.5
0.098	1
0.199	2

4. Put a star where a 50 N force would be on the graph

5. How much would you expect the spring to stretch with a 50 N force?

6. Dr. Longyear has challenged the class to make a tower made of Styrofoam 1 foot high. Which ever one can hold the most weight wins. He gives the class 5 different types of Styrofoam. Which Styrofoam would you use to build? Set up an experiment to determine which Styrofoam is best.

Connection to student achievement

In the beginning of the year, we spend a few weeks on units and measurement. This topic encompasses a basic skill all students will need as they progress through science classes in middle school and high school. In this lesson, students will have to use measurement skills and carefully track their data using the right units.

Further, students must be introduced to the scientific method and common science and engineering practices. The new NGSS standards provide a list of practices, such as creating a model, planning an investigation, using mathematical thinking, analyzing data, and communicating results. This lesson will include these skills.

Not only will students be introduced to science and engineering practices, but they will also be introduced computer coding. This is an essential 21st century skill for any student interested in pursuing science and engineering.

Finally, students will be exposed to a basic law in science, which is Hooke's law. From this lesson we can talk about the broad applications of force (F = ma) as well as the importance of stress and strain, especially in engineering applications.

Activities prior to this lesson:

Prior to this lesson, I will have gotten to know my students and their foundational knowledge. I will have assessed their ability to design and carry out experiments. Directly prior to this lesson, I will give a short survey to see how much students already computer coding as well as force and springs.

Following this survey, I will introduce my students to Matlab. I will teach them what Matlab is, the basic things it can do, and how it is used in the real world. I will then emphasize how Matlab can take problems with multiple steps and solve them quickly. I will introduce them to functions, where Matlab can do the same task over and over with different inputs. After we understand the basics of Matlab, I will give them a lesson on force. This will include a hands-on task to show how force = mass x acceleration. Finally, we will have foundation to start a 2-day experiment with springs. Here is an outline of our schedule:

Day 1: What is Matlab? Students learn Matlab basics such as variables and calculations.
Day 2: Write a function in Matlab. Students write a function that takes an input and generates on output.
Day 3: What is force? Hands-on experiment with different masses.
Day 4: How do springs work?

What follows is a detailed lesson or Day 4

Introduction to new material

How would you describe a spring? How do springs work?

Are springs the only material with these properties? Can other materials act “springy”?

One key characteristic of a spring is that when you push or pull it, it pushes or pulls right back. Remember, we called a push or a pull a ‘force’; that will come up a lot today.
Another key characteristic of a spring is that the farther you push or pull, the stronger the force is.

(Give a few students some springs)
Pull back on these springs about 1 cm. Was that hard?
Ok, try pulling back 10 cm. Was that hard?
Right, to farther you pull, the more force the spring applies.

A long time ago a man named Robert Hooke came up with a law (called Hooke’s law) that gives us an equation we can use for all springs. The equation is Force = the spring constant x distance (or $F = kx$).
So we know force and we know distance, but what is the spring constant?
Each spring can have its own spring constant. This is how hard it is to stretch.
(Give a student pull on spring with a low k, then pull on a spring with high k)
We can see that one spring is “stiffer” than the other. This one will have a higher spring constant.
We call it a constant because it doesn’t matter how far we stretch the spring. The spring constant will always be the same.
Remember, the unit for force is Newtons. The unit for distance is meters, and the unit for the spring constant is Newtons per meter (or N/m).

Ok, let’s see if we can use Hooke’s law on a couple of problems as a class.

Guided practice

(teacher puts 3 questions up on the board for students to try, and we review them as a class)

- if we have a spring that has a spring constant of 10 N/m and it stretches 1 meter, what is the force?

- What if we take that same 10 N/m and it only stretches 1 centimeter? What is the force?

- What if we know the force and the distance, but we don’t know k? how would we rearrange the equation to get k?

Guided practice with Matlab

Ok, now that we have seen how to do these equations by hand, let’s make Matlab do all the work.

Based on what we learned about Matlab, I want you to write a function that takes 2 inputs, distance and the spring constant, and gives 1 output, the force.

(students work in teams of 2 to make a Matlab code while the teacher circulates the room)

Independent practice

(students will be given 2 springs and a set of masses, similar to those below)

Ok, I will give you 2 springs and a set of weights. Here is your challenge:

- You must come up with an experiment to find the spring constant for both springs
- You must write an introduction and a methods before starting the experiment
- You must make a graph of Force vs Distance for each spring
- You must write a Matlab function that tells you the spring constant of the spring
- You must make a prediction for how much a 50 N/m spring will stretch with a 200 gram weight, a 350 gram weight, and a 750 gram weight.

We will have competitions for the last 2 parts. Whoever gets closest to the actual spring constant wins, and who ever gets closest to the stretch wins.

(Students work in small groups to write an experiment. Teacher circulates and talks to each group)
(When students start experiment, teacher examines their scientific skills and technique)
(When students write their code, teacher examines their code and guides them if needed)

Closing discussion

What do you notice about your graphs?
(they are mostly linear)

Which group got the closest for the spring constants? How did you do it?

Which group got the closest for the stretch of the 50N/m spring? How did you do it?