Forces and Springs
Grades 6-8

Lesson Overview

60 - 90 mins

During this lesson, students will design and code an experiment investigating the relationship between the force applied to a spring and how far it stretches. They will integrate Vernier sensors and SAM Labs blocks in their coding solution.

Learn Warm-Up Mini-lesson	**Identify** factors involved in the relative stiffness of springs. **Determine** the relationship between the force and the spring as it is stretched.
Do Guided Lab Part 1 Construction Activity Guided Lab Part 2 Extension Activities	**Design**, **code** and **extend** a program using a Force and Acceleration sensor that demonstrates and collects data, extending to visualize the data using a Servo Motor; to explain the factors involved in determining the spring constant (Hooke's law).
Reflect Wrap-Up	**Reflect** upon new **knowledge** of springs and spring forces.

Standards Focus

NGSS DCI MS-PS1-1, MS-ETS1-3
CSTA Data and Analysis 2-DA-07, 2-DA-08, 2-DA-09

Equipment Required

SAM Labs Servo Motor, Vernier GDX-FOR, springs, ruler or meter stick, construction/craft materials, tape

Link to lesson code on Workbench
https://edu.workbencheducation.com/cwists/preview/59877x

Forces and Springs

Learn

Warm-Up

“Where are springs in our everyday lives?”

Prior Knowledge Required

- Newton’s third law of motion: When one object (“A”) pushes or pulls on another object (“B”), object “B” pushes (or pulls) back on object “A” with the same force, but in the opposite direction.

Key Information

- Springs can be used to keep an object in place or return to a previous position, like a spring in a pen.
- Springs can be tightly coiled or expanded when at rest.
- Factors that affect the strength of a spring:
    - Type of material
    - Diameter of the coil
    - Thickness of the coiled material
    - Coils per unit length
    - Overall spring length

Unplugged Activity

- Prior to beginning the activity, create groups of two or three students and send them on a treasure hunt to find springs used in the class, school, or home.
- Using Think Pair Share, students can discuss the questions on the slides, while observing their springs.
    - What affects the stiffness of a spring?
    - Where are springs in our everyday lives?
- Students can complete a paired/independent KWL chart to record their prior knowledge, establish questions and set expectations for recording learning at the end of the lesson.

Link Forward

Students explore the relationship between force and the spring both at rest and as it is stretched.

Forces and Springs

Mini-lesson

What is the relationship between the force and the spring as it is stretched?

Key Information

- Springs are elastic.
    - This allows them to stretch, then return to their original shape without permanently changing their structure.
- Springs return to their original shape/position when no forces are applied.
- You can permanently change the structure of the material by applying too large a force.
- The larger the force you apply to a spring, the more it will stretch or compress.
- The force required to stretch a spring increases the more it is stretched.

Unplugged Activity

- Students work alone and then gather in groups of 2-3 students to compare their findings.
    - Stretch a spring a small distance. Let the spring relax and stretch it the same distance. Is the force required the second time the same as the first? Try this several times.
    - Stretch the spring twice as far. How much force do you have to use to stretch the spring twice as far?
    - If you have another spring compare the two springs. Can you guess which one is harder to stretch just by looking at it? What are the visible clues?

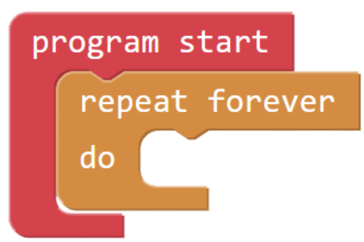
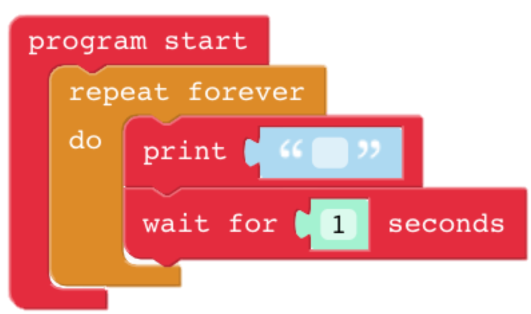
Link Forward
Students code a program to accurately measure the force being applied to the spring.

Forces and Springs

Do

Guided Lab - Part 1

Design and code a program that measures the force applied to a spring.

Instructions	Workspace
Step 1 Click 'ADD DEVICE' and select: • 'Force and Acceleration Sensor' Connect the Force and Acceleration Sensor, click 'CONNECT' and 'Pair'	 **The sensor is paired when it appears under your 'Connected Devices' menu on the left hand side of the screen.**
Step 2 From 'General', drag onto the workspace: • 1 'program start' block.	
Step 3 From 'Loops', drag onto the workspace: • 1 'repeat forever do' block. Snap into the 'program start' block.	
Step 4 From 'General', drag onto the workspace: • 1 'print [" "]' block • 1 'wait' block. Snap into the 'repeat forever do' block.	 **The print function allows you to log and view data.**

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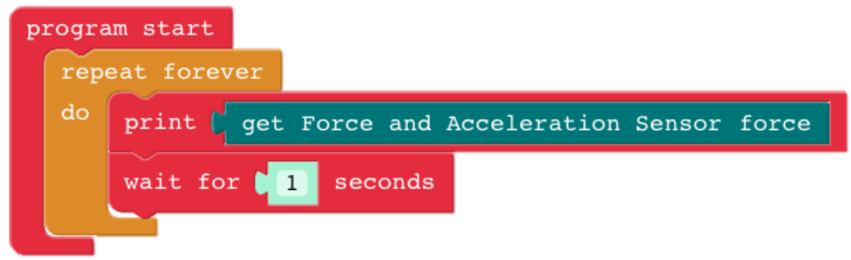
Step 5
From ‘Force and Acceleration Sensor’ tab, drag onto workspace:

- 1 ‘get Force and Acceleration Sensor force’ block.

Snap into the print [“ “]’ block.



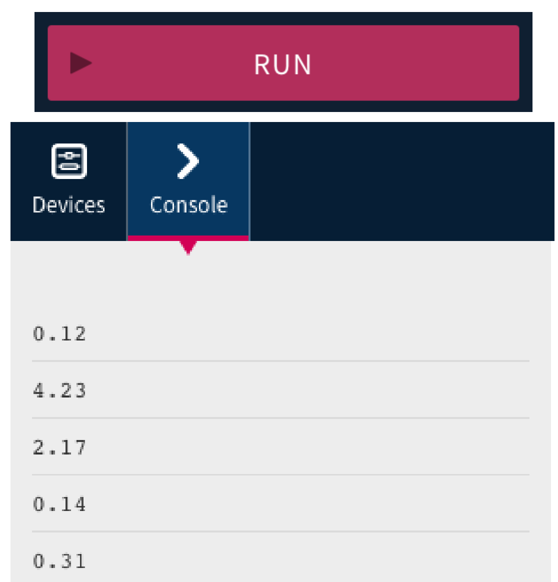
The Force and Acceleration Sensor measures forces (pushes and pulls) like on a roller coaster, swing, or trampoline. In this case, the sensor will measure the force applied to the spring being tested.

Step 6
Select a spring to test.

- Attach the spring to the sensor.

Run your program.

Run your program by clicking on the "Run" button at the top of the Programming Canvas.

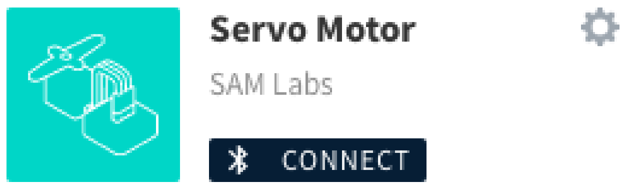
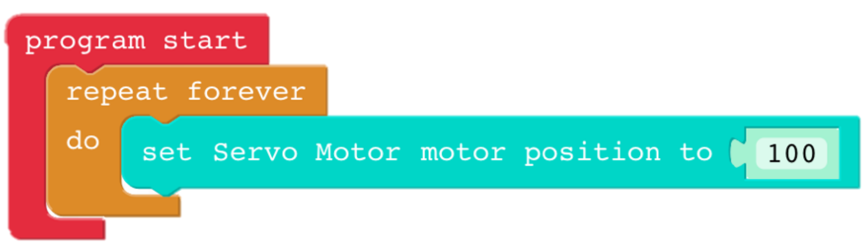


The Console will display different data points as force is applied to the spring. Pull on the spring to see the changes in force reflected in the Console data.

Link Forward
Students create a physical meter that mirrors the data they see on their screen.

Construction Activity

Design, build, and code a physical meter that mirrors the force data displayed in Workbench.

Instructions	Workspace
Step 1 Test the Servo Motor: Click 'ADD DEVICE' and select: ● 'Servo Motor Sensor' Connect the Servo Motor Sensor, click 'CONNECT' and 'Pair'.	 **The Sensor is paired when it appears under your 'Connected Devices' menu on the left hand side of the screen.** **The Servo Motor will be your needle in your 'Force Meter.'**
Step 2 From the workspace, delete the code from inside the 'repeat forever' block.	
Step 3 From 'Servo Motor> Actions', Drag onto the workspace: ● 1 'set Servo Motor Position to [ ]' block. Snap into the 'repeat forever do' block. Set Servo Motor Position to '100.'	 **Students use this code or create their own program to explore how the Servo Motor works. Encourage students to test out different position values on the Servo.**

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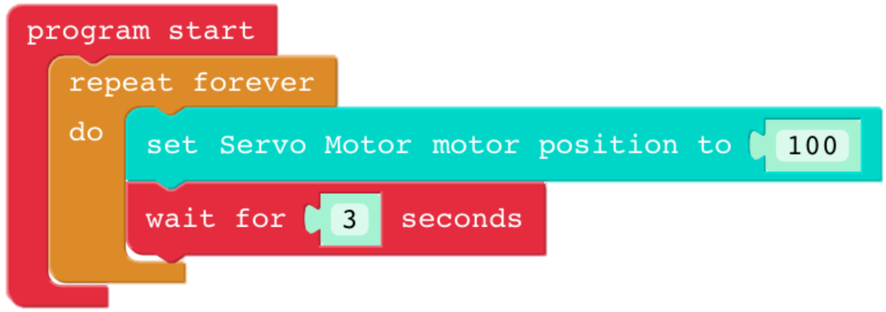
Step 4
Drag onto the workspace:

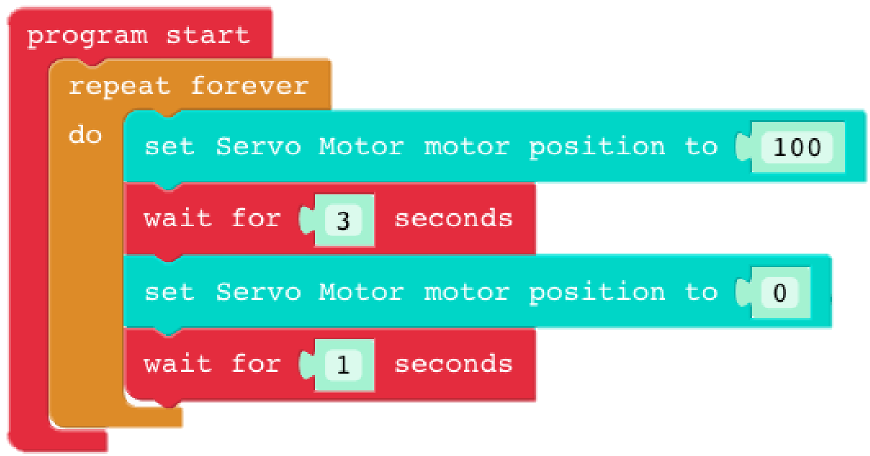
- 1 'wait' block.

Snap into the 'set Servo Motor Position to" block.

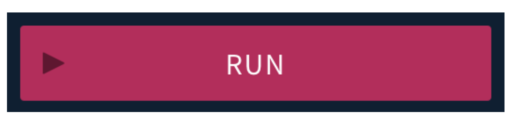
Set 'wait' block to '3' seconds.



Step 5
Repeat steps 3 and 4 but set 'Servo Motor position' block to '0' and 'wait' block to '1' seconds.



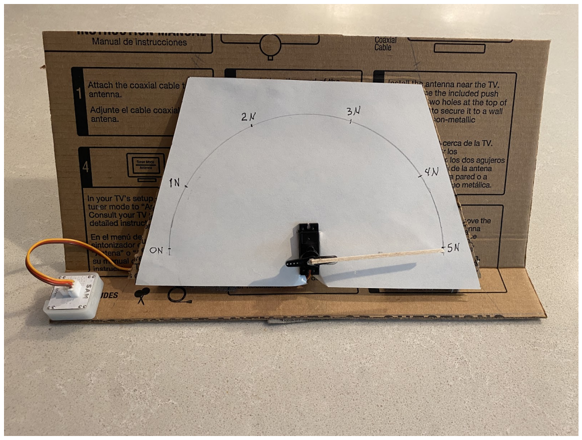
Step 7
Run your program.



Students will need to understand how the force values can be modified in their code to change the position of the Servo Motor. This is a great opportunity to discuss ratios.

The example limits the force to 5 newtons based on the spring used. Student code may need to be modified to work with different springs.

The operation of the Servo Motor may result in students creating meters that respond counterclockwise. Guided Lab 2 provides guidance for only a counterclockwise solution. Students can modify that code for clockwise in the first extension activity.



Step 8
Construct a meter using the Servo Motor out of the following materials:

- Tape
- Cardboard
- Paper

Students will draw an arch and label 0 newtons - 5 newtons. Measure to create precise tic marks equally across the arch, where 0 newtons is at 0-degrees, and 5 newtons is at 180-degrees.

Students should make sure they can access the power button and USB charging port on the Servo Motor block.

Tape a "needle" onto the arm of the Servo Motor so that it is clear what value it is pointing towards. The arm of the servo can be unscrewed and repositioned so that it lines up appropriately.

Link Forward
Students will link their visualization from the Servo Motor to the data from the Force Sensor.

Guided Lab - Part 2

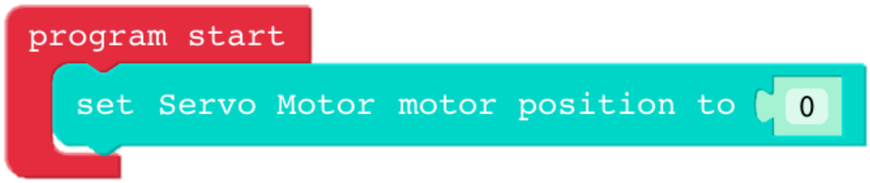
Design and code a program that will use the data from the Force and Acceleration Sensor to control the position of the Servo Motor.

Instructions

Step 1
Remove the code from inside the 'program start' block.

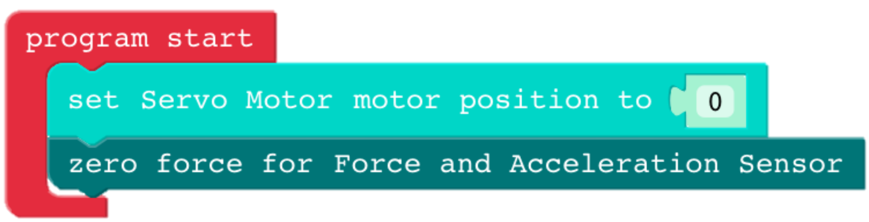
Drag back onto the workspace:
- 1 'set Servo Motor Position to 0' block.

Snap into the 'program start' block.



Step 2
From 'Force and Acceleration Sensor>Actions' tab, drag onto workspace:
- 1 'zero force for' block.

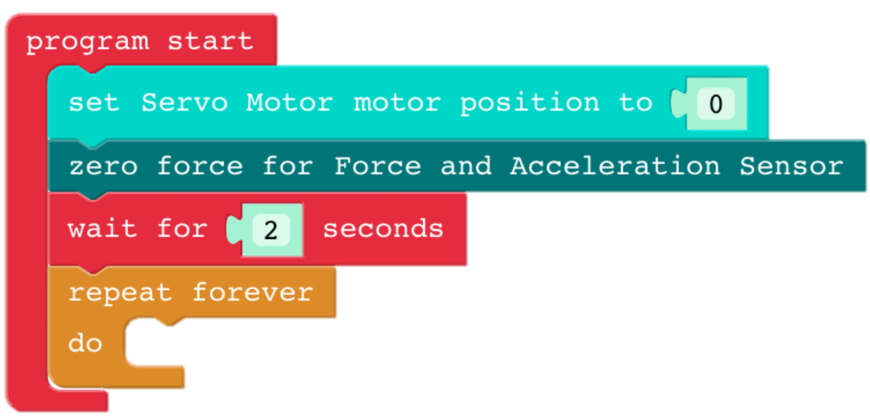
Snap into the 'set Servo Motor Position to [ ]' block.



Step 3
Drag back onto the workspace:
- 1 'wait' block.
- 1 'repeat forever do' block.

Snap into the 'zero force for' block.

Set 'wait' block to '1' seconds.



Workspace

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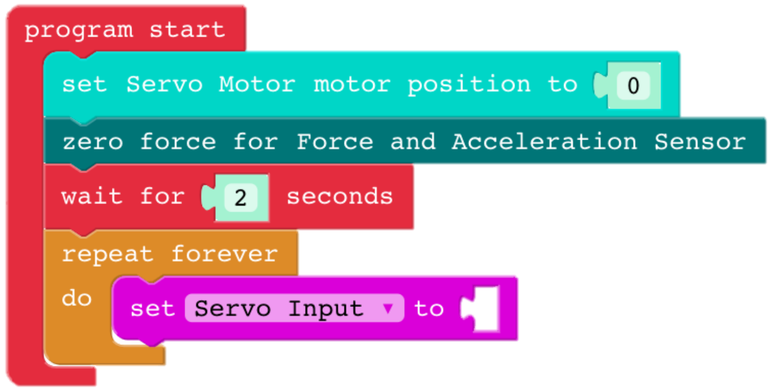
Step 4
From 'Variables', create variable 'Servo Input'. Drag onto the workspace:

- 1 'set Servo Input to' block.

Snap inside the 'repeat forever do' block.

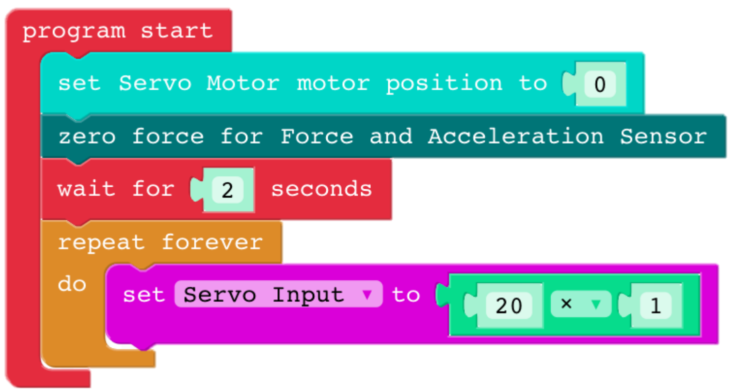


Step 5
From 'Math' tab, drag onto workspace:

- 1 '1+1' block.

Snap inside the 'set Servo Input to' block.

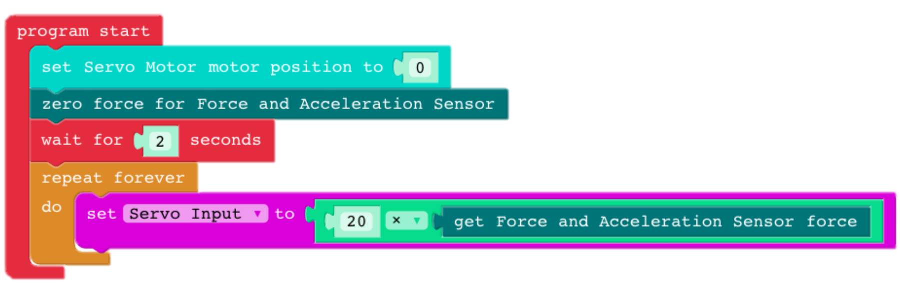
Set the '1+1' block to '20x1'.



Step 6
From 'Force and Acceleration Sensor' tab, drag onto workspace:

- 1 'get Force and Acceleration Sensor force' block.

Snap inside the '20x1' block.

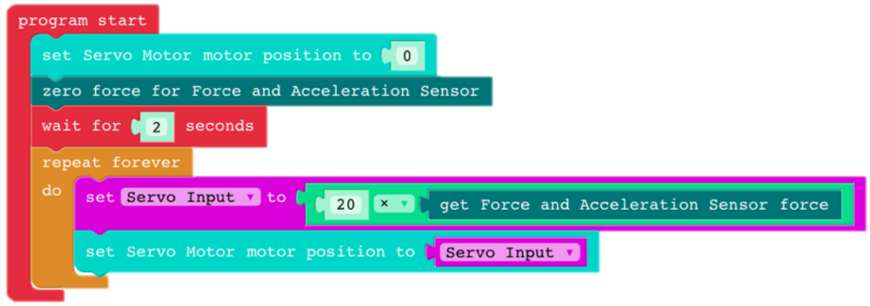


The variable Servo Input reads the value from the force sensor and multiplies it by 20. Since the upper range for our spring is 5 newtons, this allows the servo to move through the range of 0 to 100.

Step 7
Drag onto workspace:
- 1 'set Servo motor position to' block.

Snap inside the 'set servo input to' block.

Set 'Servo Motor position block' to the variable 'Servo Input.'

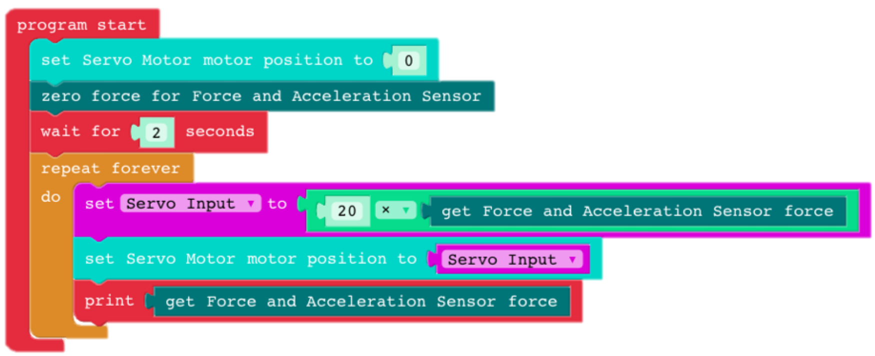


This code works for meters that are designed for clockwise motion with an expected maximum of 5 N.

Step 8
Drag onto workspace:
- 1 'Print' block
- 1 'get Force and Acceleration Sensor force' block.

Snap inside the 'set servo Motor position to' block.

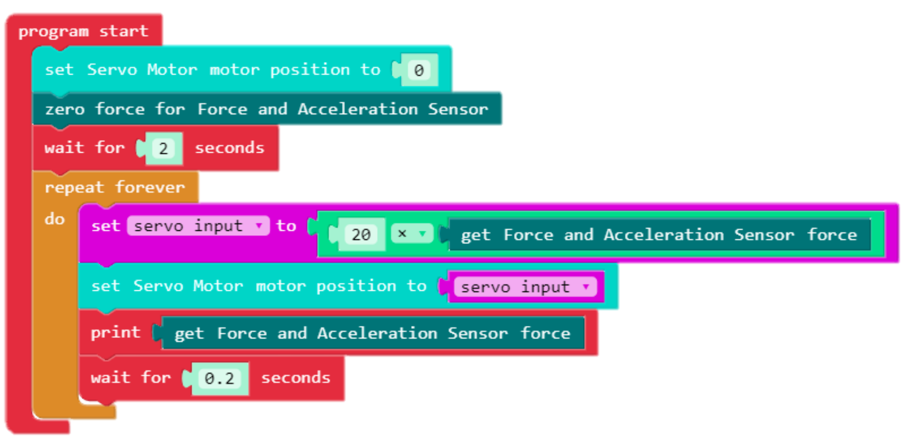
Snap "get Force and Acceleration Sensor force' into the 'Print' block.



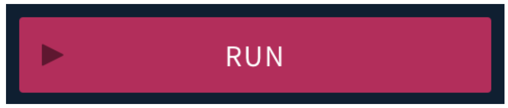
Step 9
Drag onto workspace:
- 1 'wait for' block.

Snap inside the 'print' block

Set 'wait for' block to '0.2' seconds.



Step 10
Run your program.



Students should run this program and test their spring, collecting force and spring stretch data pairs for at least 5 different forces. This initial stretch data will be collected and noted manually.

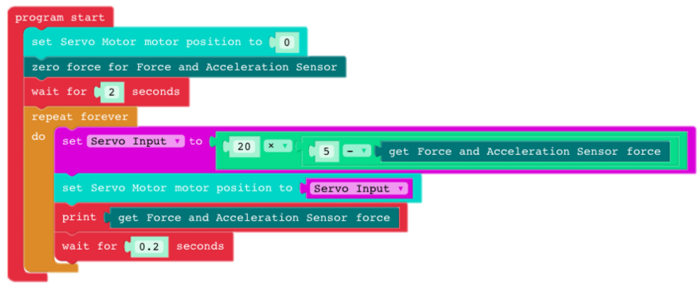
It is important that students measure how far the spring is stretched and not its entire length. It may be easier if they measure how far they pull the sensor.

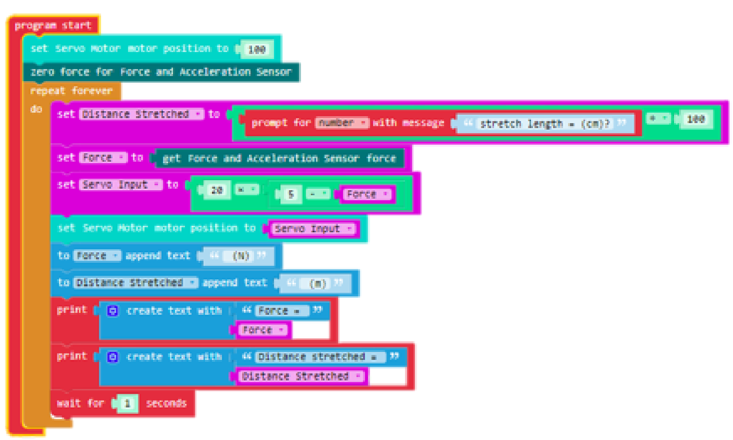
Link Forward

Students extend their program to move the servo motor counterclockwise, enter distance data, and calculate the spring constant.

Extension Activities

Code a program that turns your meter clockwise, customizes the display of force and distance data, and calculates the spring constant.

Extension 1 - Clockwise Design Brief	Workspace
Modify the code to reflect the meter moving clockwise rather than counterclockwise when displaying the data of the Force and Acceleration Sensor.	 **This shows example code that could be created to meet the design brief. This can be used to support students to develop their designs.** **This code works for meters that are designed for counterclockwise motion with an expected maximum of 5 N.**

Extension 2 - Force and Distance Design Brief	Workspace
Design and code a program that collects force data and allows you to manually enter the distance the spring is stretched.	 **This shows example code that could be created to meet the design brief. This can be used to support students to develop their designs.**

Extension 3 - Spring Constant

Design Brief

Design and code a program that collects force data, inputs spring stretch distance, and calculates the spring constant.

Workspace

This shows example code that could be created to meet the design brief. This can be used to support students to develop their designs.

The spring constant can be calculated by dividing the force by the distance the spring is stretched. This extension does require the completion of the Extension 2 - Force and Distance.

Teacher Note: Some springs are not "at rest" when they are fully released, but the coils are pushing against one another. This can result in the initial values of the spring constant being calculated as higher than actual.

Hooke's law is often represented as $F = -ks$ with the negative sign indicating that the force from the spring is in the opposite direction that it is being stretched. This point is omitted in this example code for simplicity.

Reflection Prompts

What are three of the factors that affect the stiffness of a spring?

What is one thing you could do to improve your meter? Explain what you would do.

