NYU-poly

POLYTECHNIC INSTITUTE OF NEW YORK UNIVERSITY

# The Science of Spring Force

**Subject Area(s)** Physics, Measurement

**Associated Unit** None

**Associated Lesson** None

**Activity Title:** The Science of Spring Force

**Header** Insert Image 1 here, right justified

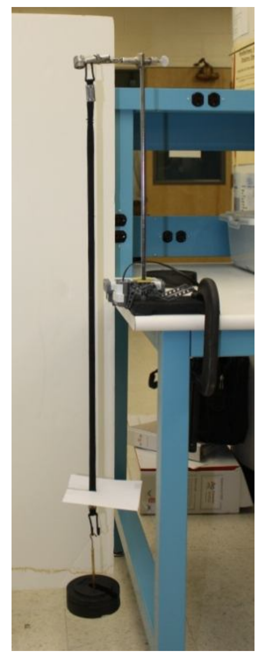

**Image 1**
**ADA Description:** An image of the Spring-Mass-Sensor setup
**Caption:** None
**Image file name:** Spring_Mass_Sensor_Setup.jpg
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**Grade Level** 8 (7 - 9)

**Activity Dependency:** None

**Time Required:** 45 mins.

**Group Size**: 6

**Expendable Cost per Group:** US $0


## Summary
Students during this activity are learning about one way of measuring a distinct property of a simple/complex machine, which involves the concept of force and displacement, as well as the use of data acquisition equipment. In the engineering world, materials and/or systems are tested by applying forces on the material or system and measuring the displacements that result. The relationship between the force applied on a material and its resulting displacement is a distinct property of the material, which is measured in order to evaluate the material for proper use in structures and machines.


## Engineering Connection
A property that mechanical engineers study and measure is the spring or stiffness constant of a material, which involves the application of Newton's Laws of motion, otherwise known as Hooke's Law. Various types of tests are conducted on different materials in order to determine the individual stiffness of each material. This is useful to determine the best type of material for the design of a structure or machine.

## Engineering Category

Category #1: relates science concept to engineering

**Keywords:** Force, displacement, spring, Lego Mindstorms NXT, data acquisition, sensor

## Educational Standards

New York Science, 2010, PS 5.1e, PS 5.2b: Newton's Third Law: For every action there is an equal and opposite reaction; Force as an interaction.

## Pre-Requisite Knowledge

A basic understanding of force and simple/complex machines and what they are useful for.

## Learning Objectives

After this activity, students should be able to:

- Understand Hooke's Law and its application to springs/elastic structures, F=kx
- Understand the difference that a material makes in the design of a simple/complex machine
- Measure properties/collect data from testing of materials

## Materials List

Each group needs:

- A spring or bungee cord
- 1 NXT with an ultrasonic sensor
- Cardboard platform on bottom end of spring/bungee cord
- Lab stand with attached clamp or rod parallel to floor

## Introduction / Motivation

Everyday machines, like cars and computers, are made up of many different parts, each with their own purpose, so that machines can move and function properly. Many machines have parts that need to move back and forth so that the machine can perform its function again and again. One of the parts used in a typical machine is a simple device called a **spring**.

A spring is an elastic device that comes back to its original position after it is pushed, pulled or bent. There are many examples of springs in everyday uses, such as (write on the classroom board)

-rubber bands

-bungee cords

-small springs used in buttons found on computers, elevators, appliances, toys

-(other examples that the kids may give)

However, not all springs are used for any type of job or use. Depending on the type of material used, as well as the size, the spring can be pushed to a different size and/or shape. The machine or device that the spring is attached to may need to move a large distance or a small distance in order for the machine or device to work well. In order to predict how far a spring would compress or stretch, a relationship between the load applied (F) and the displacement of the spring (d) is given by Hooke's Law;

$$F=kd \quad (1)$$

This equation is a linear equation, which means that it is in the form:

$$y=mx+b$$

where m is the slope and b is the y-intercept. In this case, there is no y-intercept, given that the spring starts unstretched. As in a linear equation, the slope is the relationship between x (which is d in Equation 1, above) and y (which is F in Equation 1, above). The slope shows how y changes when x changes. This is similar to the relationship seen in Equation 1. When the displacement (d) changes, the force of the spring (F) changes. The relationship, or slope, of Equation 1 is called the **stiffness** constant. It is a property of each structure or material that does not change when it is being pushed or pulled, and it indicates its resistance to movement or change in shape. Therefore, in order to measure the stiffness of a structure or material, scientists and engineers run various types of tests using different testing equipment to measure the change in length or shape of a structure or material under different loads. The equipment often uses **sensors**, which are electronic devices that measure the change in length or shape of a material as it is being pushed or pulled. Sensors that can also measure the amount of load placed on the piece of material itself are also used.

## Vocabulary / Definitions

| Word | Definition |
|---|---|
| Spring | Elastic device that returns to its original shape when it is pressed, bent, pushed, or pulled |
| Stiffness | Resistance to change of shape of a material or structure |
| Sensor | Device that measures or "senses" a specific quantity (temperature, distance, level of light/darkness |

## Procedure

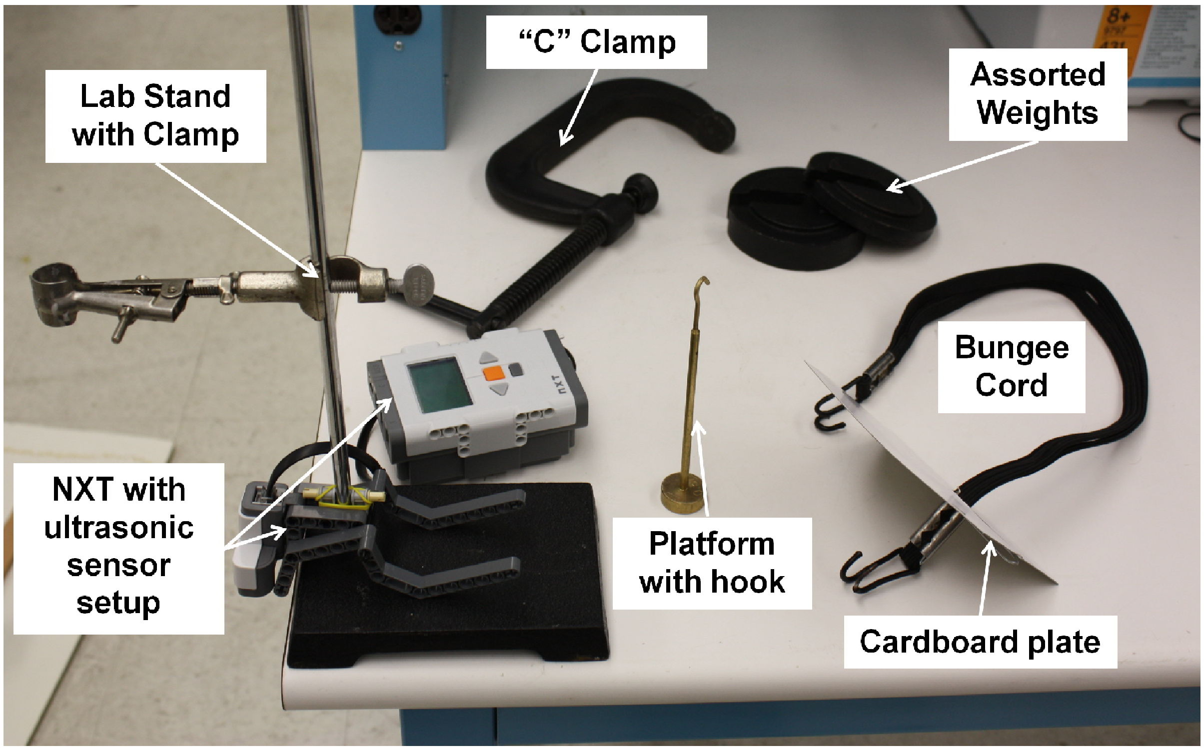
### Before the Activity

- Setup 4 stations with lab stands clamped to a table
- Attach a spring or a bungee cord to each lab stand
- Attach a cardboard plate near the bottom end of each bungee cord
- Attach an ultrasonic sensor onto the bottom of each stand using Lego pieces in order to measure the displacement
- Prepare a platform that attaches to the bottom end for weight placement

### With the Students

1. Have each group of students place the platform at the bottom end of the spring or bungee cord (if the platform is heavy enough to induce significant deflection, take the weight of the platform into account).
2. The students must then record the initial position of the cardboard plate.
3. Have the students place increments of weights on the platform and write down the position of the cardboard plate after each weight increment.
4. Using the table below, have the students calculate the displacement (d) after each weight increment. The students can plot a force vs. displacement graph by hand, or use Microsoft Excel. The slope of the graph is the stiffness constant, k.

**Image** Insert Image 2 here, center




| |
|---|
| **Image 2**<br>**ADA Description:** An image of each of the components used for the spring-mass-sensor setup<br>**Caption:** Figure 1: Spring testing setup components<br>**Image file name:** spring_testing_setup_components.jpg<br> |

## Safety Issues

- Slowly load and unload the weights to ensure the spring or bungee cord does not flail out.

## Troubleshooting Tips

- Ensure that the hanging weight is still when taking displacement measurements to ensure as accurate a reading as possible.

## Assessment

### Activity Embedded Assessment

*Analysis*

There are two criteria that students should be evaluated on: conducting experimental measurements and interpretation of the resulting data with respect to applied theory. When conducting experimental measurements, the groups should have the similar displacement results, given that the same-size spring or bungee cord should be used by each group. When interpretation of data is conducted, students should be able to obtain data from a graph that is drawn using their own obtained results. Students should then be able to have a better idea of the concept of stiffness in materials and determine the everyday materials that can be considered relatively stiff as compared to other materials.

## Activity Extensions

None

## Additional Multimedia Support

None

## Owner

Ronald Poveda

## Contributors

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## Supporting Program

AMPS Program, Polytechnic Institute of NYU

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