6.3 Equilibrium of Forces and Hooke's Law

How do you predict the force on a spring?

Springs come in two basic types. An extension spring is designed to be stretched, or *extended*. A compression spring is designed to be squeezed, or *compressed*. Hooke's law describes the relationship between force, the spring constant, and deformation.

In this investigation, you will:

- conduct experiments to determine the spring constants for an extension spring and a compression spring.
- create and test a graphical model for spring data.

Materials List

- Stand with ruler card
- 2 Extension springs
- Compression spring
- Mass hanger
- Mass holder
- 12 washers
- Electronic scale (or triple beam balance)

1 Experimenting with an extension spring

The goal of the first part of the experiment is to determine how much an extension spring extends per newton of applied force. You will measure the amount the spring extends as the applied force is changed. The data will allow you to determine the spring constant, which measures the strength of the spring.

1. Set up the Hooke's Law apparatus as shown at right.
2. Hang the blue-tabbed extension spring from the top of the stand, and attach the mass hanger with five washers on it.
3. Adjust the measurement card so the 0-cm mark lines up with the bottom of the mass hanger.
4. How much does the spring extend when you add more washers? Use Table 1 to help guide your experiment as you investigate the strength of the spring.

Table 1: Force and extension of a spring

Number of washers	Mass of holder and washers (kg)	Calculated force of holder and washers (N)	Spring's extension (cm)
5			0
7			
9			
11			

2 Analyzing the data

a. Make a graph of force versus extension for the spring.

b. The force from a spring can be described by a formula known as Hooke's law. The spring constant (k) is a measure of the strength of the spring. For example, a spring with k = 1 N/cm produces 1 newton of force for every centimeter of extension.

HOOKE'S LAW (springs)

$$F = -kx$$

Force (N): F; *Spring constant* (N/cm): k; *Deformation* (cm) (extension or compression): x

Use your graph of force versus extension to determine the spring constant for the spring in the experiment. Express your result in N/cm.

3 Testing the model

a. Use your *graph* to predict how much the spring should extend for a hanger with 15 washers.

b. Set up the experiment and test whether the graph gives the correct prediction.

c. How close did your prediction come to the actual extension of the spring? Calculate your percent error.

d. If you use the Hooke's law equation and the spring constant you found in 2b to predict the spring extension, you get a predicted extension that is greater than expected. Why is the answer off by that factor? Explain why you have to make a calculation adjustment to your experimental data to accommodate the Hooke's law equation prediction.

e. You have a second extension spring in the kit—this one has a white tab on it. Do you think this spring has a lower k value than the blue-tabbed spring you just studied, or a higher k value? Explain your choice.

f. Repeat parts 1 and 2 of this investigation with the white-tabbed spring. How do the results compare to your prediction? Explain.

4 Experimenting with a compression spring

This part of the investigation uses a compression spring. Compression springs obey Hooke's law also, but are designed to be compressed rather than extended. To measure the spring constant, you need to measure how much the spring compresses when different amounts of force are applied.

1. Place the compression spring on the spindle, with the mass holder and three washers on top, as shown at right.
2. Adjust the measurement card so the 0-cm mark lines up with the bottom of the mass holder.
3. How much does the spring compress when you add more washers? Use Table 2 to help guide your experiment as you investigate the strength of the compression spring.

Table 2: Force and compression of a spring

Number of washers	Mass of holder and washers (kg)	Calculated force of holder and washers (N)	Spring's compression (cm)
3			0
6			
9			
12			

5 Analyzing the data

a. Make a graph of force versus compression for the spring.

b. The force from a compression spring can also be described by Hooke's law. As with extension springs, the spring constant (k) is a measure of the strength of the spring. For example, a spring with k = 1 N/cm produces 1 newton of force for every centimeter of compression.

HOOKE'S LAW (springs)

$$F = -kx$$

Force (N) — F; ***Spring constant*** (N/cm) — k; ***Deformation*** (cm) (extension or compression) — x

Use your graph of force versus compression to determine the spring constant for the spring in the experiment. Express your result in N/cm.

6 Testing the model

a. Use your *graph* to predict how much the spring should compress for a holder with 15 washers.

b. Set up the experiment and test whether the graph gives the correct prediction.

c. How close did your prediction come to the actual compression of the spring? Calculate your percent error.

d. If you use the Hooke's law equation and the spring constant from 5b to predict the spring compression, you get a predicted compression that is higher than expected. Why is the answer off by that factor? Explain why you have to make a calculation adjustment to your experimental data to accommodate the Hooke's law equation prediction.

e. Could this spring be used to measure the mass of one washer? If so, explain a procedure for how to make the measurement. If not, explain why not.

f. How much force would it take to cause a compression of 1 millimeter?