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Linked Spring Series
#SPRING5

Warning:

- **Not a toy; use only in a laboratory or educational setting.**
- **California Proposition 65 Warning: This product can expose you to chemicals including nickel and lead, which are known to the State of California to cause cancer, birth defects, or other reproductive harm. For more information go to www.P65Warnings.ca.gov.**

$$F = -kX$$

- **F = Force (N)**
- **k = Spring Constant (N/m)**
- **X = Extension of the Spring (m)**

Introduction

The term **elasticity** is used to refer to the physical property of an object or material that allows it be stretched or compressed by a force and return to its original shape when the force is removed. Between 1660 and 1678, British physicist Robert Hooke laid out the first mathematical description of this phenomenon in what has been coined **Hooke's Law.** It is written out on the left-hand side of this page.

Hooke's Law was a groundbreaking discovery. It paved the way for areas of study such as seismology and acoustics, and, by using it to understand the power of using springs to store mechanical energy, scientists were able to engineer vital tools like the spring scale, the manometer pressure gauge, and watches.

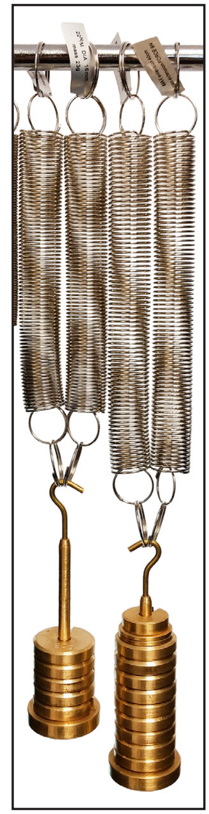
Springs are the quintessential example used when describing Hooke's Law. This kit comes with a set of five identical springs that you can use to verify it. They each have the following characteristics:

- Mass: 23g
- Diameter: 16mm
- Max. Extension: 40cm
- Max. Extension Force: 9N
- Spring Constant: 22N/m

You can use a single spring to verify your **spring constant** and prove Hooke's Law, but you can also use multiple springs to combine them in **series** or **parallel.** To do so, you will need the following **additional supplies:**

- Ruler
- Support Stand
- Metal Rod
- Clamp to Attach Rod Perpendicularly to the Support Stand
- Weights with Hangers (At least two Different Weights)

Hooke's Law and Linked Springs



Parallel Springs

Hooke's Law ties together three properties of a spring system: the spring constant, the distance a spring in stretched or compressed, and the force that was used to stretch or compress it. The force is equal to the product of the spring constant and the change in distance **(F = -k x).**

It is also important to know that force is also equal to the product of an object's mass and its acceleration **(F = m a).** Since we are using hanging weights in this demonstration, the acceleration of all weights used here will be equal to the acceleration of Earth's gravity: $9.8 m/s^2$.

The negative sign in Hooke's Law is typically included in the equation to describe the **restorative force,** or the force required to return a stretched or compressed elastic object to its original state of equilibrium. The restorative force of an elastic object is an example of the equal and opposite forces described in Newton's third law. For the purposes of proving Hooke's Law on the following page, the negative sign can be ignored to simplify the math.

Hooke's Law is used to describe a spring within its elastic limits, meaning that an elastic object can deform if it is stretched too far, and it will no longer be able to return to equilibrium. As stated on your springs, they each have a maximum extension of 40cm. **Exceeding 40cm of extension will harm your springs**.

Spring systems can also be expanded by linking two or more springs together. They can be linked in parallel or series configurations. Linked springs still obey Hooke's Law, but the spring constant value **k** here is equal to the combined spring constant of each linked spring.

All springs that are considered **parallel** are suspended from the same point (e.g. our perpendicular metal rod), and they are all attached to the force in the system. In a parallel spring system, the combined spring constant is equal to the sum each individual spring's spring constant value.

Series Springs

Springs that are considered to be linked in **series**, on the other hand, have one spring suspended from the support rod with each subsequent spring attached to the end of the one before it. Only the spring on the bottom of the series is attached to the force in the system. In a series spring system, the combined spring constant is equal to the inverse of the sum of the reciprocal of each individual spring's spring constant value.

Spring Constant in Parallel Linked Springs

$$k = k_1 + k_2 \ldots$$

Spring Constant in Series Linked Springs

$$k = \left(\frac{1}{k_1} + \frac{1}{k_2} \ldots \right)^{-1}$$

On the following page you will learn how to observe Hooke's Law in each one of the situations described above.

How to Use

Below you will learn how to set up your springs so that you can prove Hooke's Law for a single spring, a parallel spring system, and a series spring system:

Single Spring

1. Set up your support stand and rod so that you have a perpendicular bar to hang your spring from.
2. Suspend one spring from your rod by threading it through the metal loop at the top of the spring.
3. Measure the length of your spring. **(Note:** You will need to convert this measurement to meters so that your units match up with the Newton/meters used in the spring constant value.**)**
4. Suspend a weight from your spring.
5. Measure the length of your spring now that the weight is suspended from it.
6. Subtract the value recorded in step 5 from the value recorded in step 3. This will give you your **x** value.
7. Multiply the mass of your weight by the acceleration of gravity to find your force **(F)** value.
8. Insert your values into Hooke's Law and solve for the spring constant **(k).**
9. Repeat steps 3 through 8 with a weight of a different mass. Verify that your spring constant is still the same. For each different weight that you try, you will find that the force and change in distance are proportionally linked to each other. If you were to plot this data on a line graph, you would find that they are linearly related.

Parallel Linked Springs

1. Set up your support stand and rod so that you have a perpendicular bar to hang your springs from.
2. Suspend two springs from your rod..
3. Measure the length of your spring system. **(Note:** You will need to convert this measurement to meters so that your units match up with the Newton/meters used in the spring constant value.**)** Since you are using identical springs, you won't need to worry about any situation where your springs are being unevenly pulled by your force. This will allow for one simple **x** value.
4. Suspend a weight so that it hangs from the bottom of each spring simultaneously. **(Note:** You can use a length of string or a bent paper clip if you need it to make attaching your weight easier.**)**
5. Measure the length of your spring system now that the weight is suspended from it.
6. Subtract the value recorded in step 5 from the value recorded in step 3. This will give you your **x** value.
7. Multiply the mass of your weight by the acceleration of gravity to find your force **(F)** value.
8. Insert your values into Hooke's Law and solve for the spring constant **(k).** This will be the combined spring constant value made up of the sum of the constants from each spring in the system.
9. Repeat the experiment with up to five springs linked in parallel. Try different weights as well. Observe how the combined spring constant responds to these changes.

Series Linked Springs

1. Set up your support stand and rod so that you have a perpendicular bar to hang your springs from.
2. Suspend one spring from your rod.
3. Hang a second spring from the bottom of the spring hanging from the rod.
4. Measure the length of your spring system. **(Note:** You will need to convert this measurement to meters so that your units match up with the Newton/meters used in the spring constant value.**)**
5. Suspend a weight from the bottom of lowest hanging spring.
6. Measure the length of your spring system now that the weight is suspended from it.
7. Subtract the value recorded in step 5 from the value recorded in step 3. This will give you your **x** value.
8. Insert your values into Hooke's Law and solve for the spring constant **(k).** This will be the combined spring constant value made up of the inverse of the sum of the reciprocals of the constants from each spring in the system.
9. Repeat the experiment with up to five springs linked in series. Try different weights as well. Observe how the combined spring constant responds to these changes.