



Flipping Physics Lecture Notes:

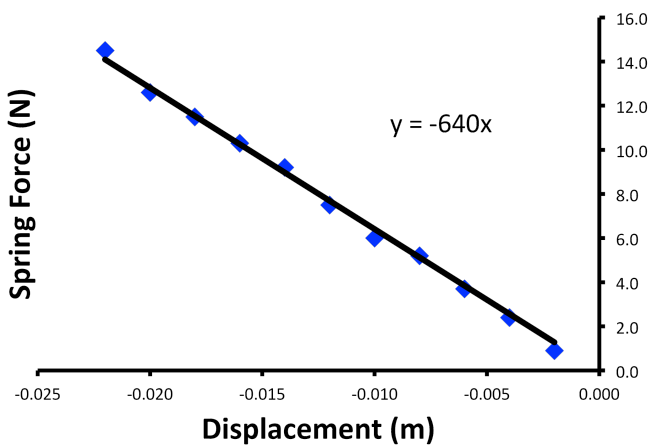
Hooke's Law Introduction - Force of a Spring

Robert Hooke* (1635–1703) was an English scientist whose “research and experiments ranged from astronomy to biology to physics; he is particularly recognized for the observations he made while using a microscope and for ‘Hooke’s Law’ of elasticity.” † Hooke is also credited being the first to apply “the word ‘cell’ to describe the basic unit of life.” ‡



In our demonstration we are taking a spring and measuring the force it takes to compress the spring a certain distance.

When we graph this data with the force of the spring on the y-axis and the displacement of the spring on the x-axis, we get this result.

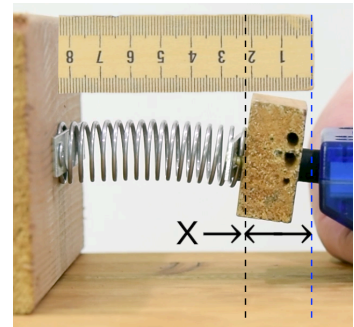


Push	
Spring Force (N)	Position (m)
0.9	-0.002
2.4	-0.004
3.7	-0.006
5.2	-0.008
6.0	-0.010
7.5	-0.012
9.2	-0.014
10.3	-0.016
11.5	-0.018
12.6	-0.020
14.5	-0.022

Hopefully you recognize that there is a linear relationship between the force and displacement of the spring.

This relationship is called “Hooke’s Law”: $\vec{F}_s = -k\vec{x}$

- F_s is the force caused by the spring.
- k is called the “spring constant”.
 - The spring constant usually has units of newtons per meter: $\vec{F}_s = -k\vec{x} \Rightarrow k = -\frac{\vec{F}_s}{\vec{x}} \Rightarrow \frac{N}{m}$
 - Note: It could be in newtons per cm, dynes per mm, pounds per furlong, etc.
 - k is a measure of how much force it takes to compress or expand a spring per linear meter.
 - Sometimes I have seen it called “force constant”, however, I will not call it that.
 - The spring constant is always positive.
- x is the displacement from equilibrium position or rest position.
 - Equilibrium position or rest position is where the spring is located without any external force causing the spring to compress or expand. It is where the spring is at “rest”.

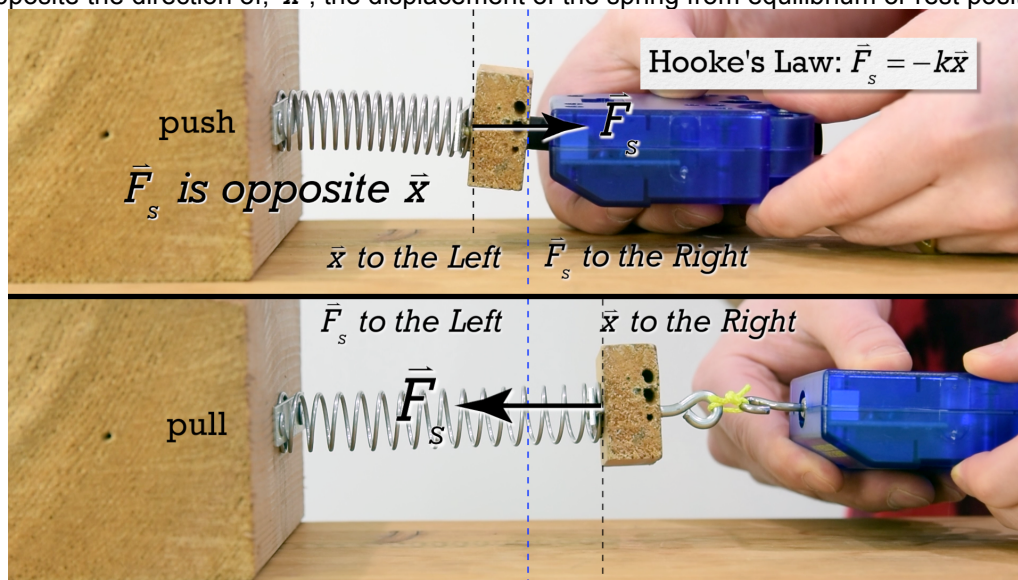


* https://en.wikipedia.org/wiki/File:13_Portrait_of_Robert_Hooke.JPG Interesting tidbit of information: “As no contemporary portrait

† <https://www.biography.com/people/robert-hooke-9343172>

‡ <http://www.history-of-the-microscope.org/robert-hooke-microscope-history-micrographia.php>

- The negative in the equation $\vec{F}_s = -k\vec{x}$ indicates that the direction of, \vec{F}_s , the force of the spring is opposite the direction of, \vec{x} , the displacement of the spring from equilibrium or rest position.



- Hooke's Law means the force required to compress or expand a spring is linearly proportional to the distance the spring is compressed or expanded.
- Going back to our original spring and data, the equation for the best-fit line of the graph is

$\vec{F}_s = -640\vec{x}$, that means the spring constant of that spring, $k = 640 \frac{N}{m}$. And we can use that

equation to predict data. For example:

- $\vec{F}_s = -640\vec{x} = -(640)(-0.019) = 12.16 \approx 12N$
 - $\vec{F}_s = -640\vec{x} \Rightarrow \vec{x} = -\frac{\vec{F}_s}{k} = -\frac{11}{640} = -0.01719 \approx -0.017m$
- Restoring Force: The spring force is a restoring force, a force that is always towards equilibrium. In other words, the force tends to bring the object back to the rest position.
- Elastic Limit: The maximum displacement before the spring will be permanently deformed. In other words, once the spring reaches beyond its elastic limit, the spring will no longer return to its original shape and Hooke's Law no longer holds true.
- Note: The AP Physics 1 equation sheet has Hooke's Law as: $|\vec{F}_s| = k|\vec{x}|$. This gives only the magnitude of the force of the spring and ignores the direction.
 - I prefer to use $\vec{F}_s = -k\vec{x}$ because it includes the direction of the force of the spring.

