

SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

This project was funded in part by the National Science Foundation. Opinions expressed are those of the authors and not necessarily those of the Foundation. The SS&C Project encourages reproduction of these materials for distribution in the classroom. For permission for any other use, please contact SS&C, National Science Teachers Association, 1840 Wilson Blvd., Arlington, VA 22201-3000.

Copyright 1996 National Science Teachers Association.





SCOPE, SEQUENCE, and COORDINATION

SS&C Research and Development Center

Gerry Wheeler, *Principal Investigator*
Erma M. Anderson, *Project Director*
Nancy Erwin, *Project Editor*
Rick McGolerick, *Project Coordinator*
Arlington, Va., 703.312.9256

Evaluation Center

Frances Lawrenz, *Center Director*
Doug Huffman, *Associate Director*
Wayne Welch, *Consultant*
University of Minnesota, 612.625.2046

Houston SS&C Materials Development and Coordination Center

Linda W. Crow, *Center Director*
Godrej H. Sethna, *School Coordinator*
University of Houston-Downtown, 713.221.8583

Houston School Sites and Lead Teachers

Jefferson Davis H.S., Lois Range
Lee H.S., Thomas Ivy
Jack Yates H.S., Diane Schranck

California Coordination Center

Tom Hinojosa, *Center Coordinator*
Santa Clara, Calif., 408.244.3080

California School Sites and Lead Teachers

Sherman Indian H.S., Mary Yarger
Sacramento H.S., Brian Jacobs

Iowa Coordination Center

Robert Yager, *Center Director*
University of Iowa, 319.335.1189

Iowa School Sites and Lead Teachers

Pleasant Valley H.S., William Roberts
North Scott H.S., Mike Brown

North Carolina Coordination Center

Charles Coble, *Center Co-Director*
Jessie Jones, *School Coordinator*
East Carolina University, 919.328.6172

North Carolina School Sites and Lead Teachers

Tarboro H.S., Ernestine Smith
Northside H.S., Glenda Burrus

Puerto Rico Coordination Center*

Manuel Gomez, *Center Co-Director*
Acenet Bernacet, *Center Co-Director*
University of Puerto Rico, 809.765.5170

Puerto Rico School Site

UPR Lab H.S.

* * * * *

Pilot Sites

Site Coordinator and Lead Teacher
Fox Lane H.S., New York, Arthur Eisenkraft
Georgetown Day School, Washington, D.C.,
William George
Flathead H.S., Montana, Gary Freebury
Clinton H.S., New York, John Laffan*

*not part of the NSF-funded SS&C Project.

Advisory Board

- Dr. Rodney L. Doran** (Chairperson),
University of Buffalo
- Dr. Albert V. Baez**, Vivamos Mejor/USA
- Dr. Shirley M. Malcom**, American Association
for the Advancement of Science
- Dr. Shirley M. McBay**, Quality Education for Minorities
- Dr. Paul Saltman**, University of California-San Diego
- Dr. Kendall N. Starkweather**, International
Technology Education Association
- Dr. Kathryn Sullivan**, Ohio Center of
Science and Industry

Project Associates

- Bill G. Aldridge**
SciEdSol, Henderson, Nev.
- Dorothy L. Gabel**
Indiana University
- Stephen G. Druger**
Northwestern University
- George Miller**
University of California-Irvine

Student Materials

Learning Sequence Item:

921

Forces Acting on a Spring

March 1996

Adapted by: *Bill G. Aldridge*

Contents

Lab Activities

1. Springs and Things
2. Measuring Force and Stretch
3. Wires as Springs

Readings

1. Explaining the Power of Springing Bodies (*Original observations by Robert Hooke*)

Science as Inquiry

Springs and Things**How do things stretch?****Overview:**

How can you make something stretch? You actually do this quite often. Think about it! You stretch a rubber band to put around something. You stretch the spring holding a door every time you open or close that door. How many boxes, doors, or lids do you open or close that use a spring to hold the lid or door closed? Cars have springs that stretch and compress as the car goes over bumps. When you play any sport involving balls, like baseball, football, or tennis, the ball is compressed when it hits something. These distortions of elastic materials have very important practical applications, but they are also of fundamental importance in science. This first activity is qualitative and observational. You are just going to make careful observations when something elastic is stretched.

Procedure:

Start with something simple—a rubber band. Hold one end of the rubber band and pull on the other end. Suppose that we define as positive the direction that the rubber band stretches when you pull it. In what direction, positive or negative, is the force you exert on the rubber band when you stretch it? In what direction is the force, positive or negative, exerted by the rubber band on your hand during the time that it is being stretched? Draw illustrations in your notebook, using arrows to show these forces and their directions. Do the same for two or three other rubber bands of various thicknesses. Repeat this simple experiment with several small springs, each having a different stiffness.

Place your hand on a soccer ball held between your hand and the floor and push hard, observing the direction of forces. Now, clamp one end of a thin metal ruler to a tabletop. Push down or lift up on the free end, bending the metal ruler. Again, observe the direction of forces.

Questions:

1. When stretching the rubber bands, how does the magnitude of the force required change from rubber band to rubber band based upon thickness (or stiffness)?

1. What is the direction of the force you need to distort the soccer ball? What is the direction of the force exerted by the ball on your hand?

2. What is the direction of the force you exert on the ruler and of the force that the ruler exerts on your hand? How does the force feel as you increase the amount of bending?

Science as Inquiry

Measuring Force and Stretch**How does the stretch of a spring relate to the force stretching it?****Overview:**

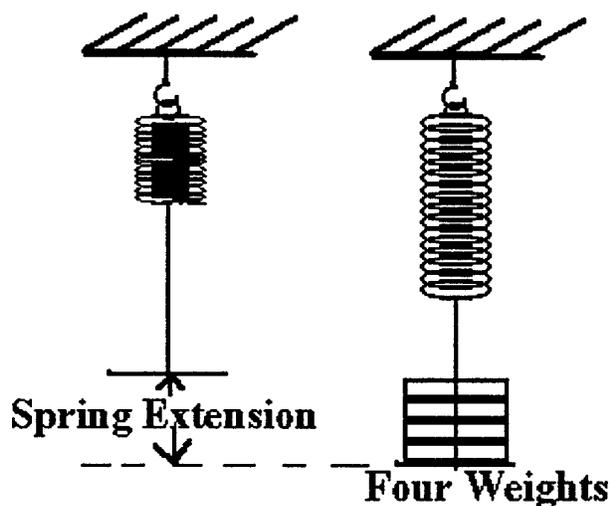
You have already learned that the force you exert on a spring to stretch it is in the same direction as the stretch, whereas the force exerted by the spring is opposite to the direction of the extension. You also learned qualitatively that the more you stretch a spring, the more force you must exert. To investigate this relationship further you need to measure the amount of stretch and the force needed to produce that amount.

Procedure:

As you have already learned, the weight of an object is a force. This means that you can use almost any collection of objects that have the same weight to apply a force to the spring. For example, most school labs have 100-gram masses used as weights. You could use several of these masses and a weight holder. This experiment could also be done at home using a variety of different objects as weights. You might, for example, use several large washers, or you might use ball bearings of the same size or marbles of the same size—then you would just need a container that could be attached to the spring.

Although science is more exact if you use certain agreed upon units of force (newtons) and spring extensions (meters), this is not necessary when you are just trying to discover the relationship itself. Here you can just say 1, 2, 3, 4, etc., units of force (e.g., for one weight, two weights, three weights, etc.). For extension you can measure in any convenient unit (e.g., centimeters).

Set up your experimental arrangement as shown here. As you add weights the spring is extended. Measure that extension in centimeters. Take measurements of extension for each added weight from one to five or six total weights. Then make a graph with extension on the vertical axis and force in number of weights on the horizontal axis. Do this for springs of two different stiffnesses.



Questions:

1. What is the appearance of each of the graphs for your two springs?
2. What is the value of the slope (amount of rise divided by amount of run) for each spring?
3. How does the stiffness of the two springs compare as you stretch them? Is the slope greater for the stiffer spring or for the spring that is less stiff?
4. If you had a third spring that was stiffer than either of these springs, how would the slope of a graph of its extension versus weight compare with that of these two springs?

Science as Inquiry

Wires as Springs**How does a wire stretch?****Overview:**

The English scientist Robert Hooke first discovered the relationship between the force on a spring and its extension about 1660. But he did not publish this discovery until 1678. In 1676 he published an anagram at the end of an article he published on helioscopes. The anagram was: *ceiinossttuu*. Now the problem for the reader who wanted to know what Hooke had discovered but did not yet have time to publish, would be to put these letters in the right order to make words—and the words were in Latin. Two years later Hooke published his paper on springs, and he translated the anagram as: *ut tensio, sic vis*, which roughly translated means "as the tension (force) so the stretch."

One of Hooke's "springs" was a long piece of wire, some 30 feet long, which he fixed at the top and stretched with weights. When the weights were removed, the wire went back to its normal position. It stretched like a spring. In this activity, you'll conduct your own experiment using a wire and weights.

Procedure:

Using a fairly thin length of steel wire, fix one end to the ceiling of your classroom. Attach a weight holder to the lower end of the wire, and carefully measure the distance from the bottom of the weight holder to the floor. Add weights, stretching the wire, and record your measurements of number of weights and amount the wire is stretched. To be sure that the wire has not been permanently distorted, take off weights one at a time until you have removed them all. Does the wire go back to its original position, as measured from the floor to the weight holder? If so, the wire was not permanently stretched.

Questions:

1. Make a graph with wire extension on the vertical axis and number of weights producing this extension on the horizontal axis.
2. How does the slope of this graph compare with the slope of the graphs for springs? You will need to use the same units of weight, and since you probably needed much larger weights for the wire than for the springs, you will need to figure out how to express this force properly.
3. If you had a coiled spring, as in older mechanical clocks and watches, how do you think such a spring would behave as the outer part of the spring is rotated? Hooke also measured these effects for such coiled springs.

History and Nature of Science

LECTURES
De Potentia Restitutiva,
 OR OF
 SPRING

Explaining the Power of Springing Bodies.

To which are added some

COLLECTIONS

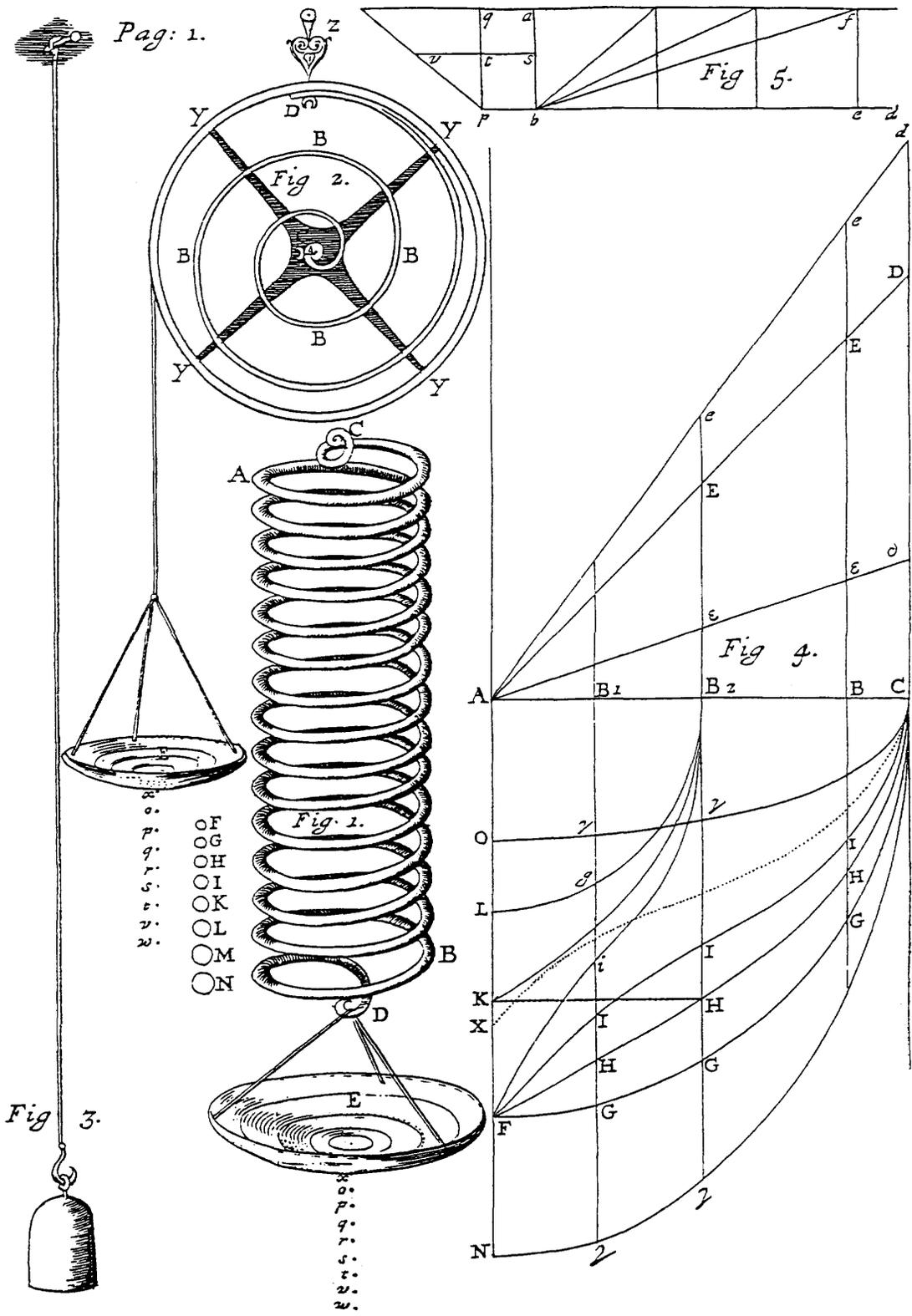
Viz.

*A Description of Dr. Pappins Wind-Fountain and Force-Pump.
 Mr. Young's Observation concerning natural Fountains.
 Some other Considerations concerning that Subject.
 Captain Sturmy's remarks of a Subterraneous Cave and Cistern.
 Mr. G. T. Observations made on the Pike of Teneriff, 1674.
 Some Reflections and Conjectures occasioned thereupon.
 A Relation of a late Eruption in the Isle of Palma.*

By ROBERT HOOKE. S.R.S.

LONDON,

Printed for John Martyn Printer to the Royal Society,
 at the Bell in St. Pauls Church-Yard, 1678.



Potentia Restitutiva,

OR

SPRING.



The Theory of Springs, though attempted by divers eminent Mathematicians of this Age has hitherto not been Published by any. It is now about eighteen years since I first found it out, but designing to apply it to some particular use, I omitted the publishing thereof.

About three years since His Majesty was pleased to see the Experiment that made out this Theory tried at *White-Hall*, as also my Spring Watch.

About two years since I printed this Theory in an Anagram at the end of my Book of the Descriptions of Helioscopes, *viz. c e i i i n o s s s t t u u, id est, Ut tensio sic vis*; That is, The Power of any Spring is in the same proportion with the Tension thereof: That is, if one power stretch or bend it one space, two will bend it two, and three will bend it three, and so forward. Now as the Theory is very short, so the way of trying it is very easie.

Take then a quantity of even-drawn Wire, either Steel, Iron, or Brass, and coil it on an even Cylinder into a Helix of what length or number of turns you please, then turn the ends of the Wire into Loops, by one of which suspend this coil upon a nail, and by the other sustain the weight that you would have to extend it, and hanging on several Weights observe exactly to what length each of the weights do extend it beyond the length that its own weight doth stretch it to, and you shall find that if

B one

one ounce, or one pound, or one certain weight doth lengthen it one line, or one inch, or one certain length, then two ounces, two pounds, or two weights will extend it two lines, two inches, or two lengths; and three ounces, pounds, or weights, three lines, inches, or lengths; and so forwards. And this is the Rule or Law of Nature, upon which all manner of Restituent or Springing motion doth proceed, whether it be of Rarefaction, or Extension, or Condensation and Compression.

Or take a Watch Spring, and coil it into a Spiral, so as no part thereof may touch another, then provide a very light wheel of Brass, or the like, and fix it on an arbor that hath two small Pivots of Steel, upon which Pivot turn the edge of the said Wheel very even and smooth, so that a small silk may be coyled upon it; then put this Wheel into a Frame, so that the Wheel may move very freely on its Pivots; fasten the central end of the aforesaid Spring close to the Pivot hole or center of the frame in which the Arbor of the Wheel doth move, and the other end thereof to the Rim of the Wheel, then coyling a fine limber thread of silk upon the edge of the Wheel hang a small light scale at the end thereof fit to receive the weight that shall be put thereinto; then suffering the Wheel to stand in its own position by a little index fastned to the frame, and pointing to the Rim of the Wheel, make a mark with Ink, or the like, on that part of the Rim that the Index pointeth at; then put in a drachm weight into the scale, and suffer the Wheel to settle, and make another mark on the Rim where the Index doth point; then add a drachm more, and let the Wheel settle again, and note with Ink, as before, the place of the Rim pointed at by the Index; then add a third drachm, and do as before, and so a fourth, fifth, sixth, seventh, eighth, &c. suffering the Wheel to settle, and marking the several places pointed at by the Index, then examine the

Distances

Distances of all those marks, and comparing them together you shall find that they will all be equal the one to the other, so that if a drachm doth move the Wheel ten degrees, two drachms will move it twenty, and three thirty, and four forty, and five fifty, and so forwards.

Or take a Wire string of twenty, or thirty, or forty foot long, and fasten the upper part thereof to a nail, and to the other end fasten a Scale to receive the weights: Then with a pair of Compasses take the distance of the bottom of the scale from the ground or floor underneath, and set down the said distance, then put in weights into the said scale in the same manner as in the former trials, and measure the several stretchings of the said string, and set them down. Then compare the several stretchings of the said string, and you will find that they will always bear the same proportions one to the other that the weights do that made them.

The same will be found, if trial be made, with a piece of dry wood that will bend and return, if one end thereof be fixt in a horizontal posture, and to the other end be hanged weights to make it bend downwards.

The manner of trying the same thing upon a body of Air, whether it be for the rarefaction or for the compression thereof I did about fourteen years since publish in my *Micrographia*, and therefore I shall not need to add any further description thereof.

Each of these ways will be more plainly understood by the explanations of the annexed figures.

The first whereof doth represent by A B the coil or helix of Wire, C the end of it, by which it is suspended, D the other end thereof, by which a small Scale E is hanged, into which putting Weights as F G H I K L M N, singly and separately they being in proportion to one another as 1 2 3 4 5 6 7 8, the Spring will be thereby equally stretcht to o, p, q, r, s, t, u, w,

B 2

that

that is, if F stretch it so as the bottom of the Scale descend to o , then G will make it descend to p , H to q , I to r , K to s , L to t , M to u , and N to w , &c. So that $x o$ shall be one space, $x p$, 2, $x q$, 3, $x r$, 4, $x s$, 5, $x t$, 6, $x u$, 7, $x w$, 8.

The second figure represents a Watch Spring coyled in a Spiral by C A B B B D, whose end C is fixed to a pin or Axis immovable, into the end of which the Axis of a small light Wheel is inserted, upon which it moves; the end D is fixed to a pin in the Rim of the Wheel $y y y y$, upon which is coyled a small filk, to the end of which is fixed a Scale to receive the weights. To the frame in which these are contained is fixed the hand or Index z ; then trying with the former weights put into the Scale E, you will find that if F put into the Scale E sinks the bottom of it x to o , then G will sink it to p , and H to q , I to r , K to s , L to t , and z will point at 1, 2, 3, 4, 5, 6, 7, 8 on the Wheel.

The trials with a straight wire, or a straight piece of wood laid Horizontal are so plain they need not an explication by figure, and the way of trying upon Air I have long since explained in my *Micographia* by figures.

From all which it is very evident that the Rule or Law of Nature in every springing body is, that the force or power thereof to restore it self to its natural position is always proportionate to the Distance or space it is removed therefrom, whether it be by rarefaction, or separation of its parts the one from the other, or by a Condensation, or crowding of those parts nearer together. Nor is it observable in these bodys only, but in all other springy bodies whatsoever, whether Metal, Wood, Stones, baked Earths, Hair, Horns, Silk, Bones, Sinews, Glafs, and the like. Respect being had to the particular figures of the bodies bended, and the advantagious or disadvantageous ways of bending them.