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.

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

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Student Materials

Learning Sequence Item:

921

Forces Acting on a Spring

March 1996
Adapted by: *Bill G. Aldridge*

Contents

This micro-unit was adapted by **Bill G. Aldridge** (SciEdSol, Henderson, Nev.)

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:

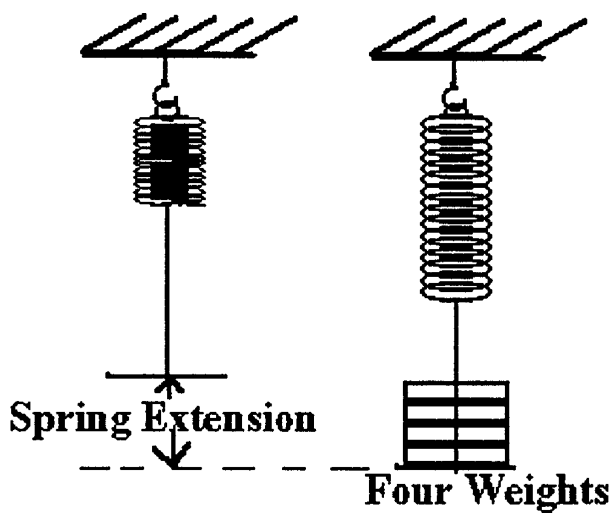
You have already learned that the force you exert on a spring to stretch it is in the same direction as the stretch, whereas the force exerted by the spring is opposite to the direction of the extension. You also learned qualitatively that the more you stretch a spring, the more force you must exert. 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 weught, 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?

Student Sheet

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: *ceiiinosssttuu.* 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 uis,* 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

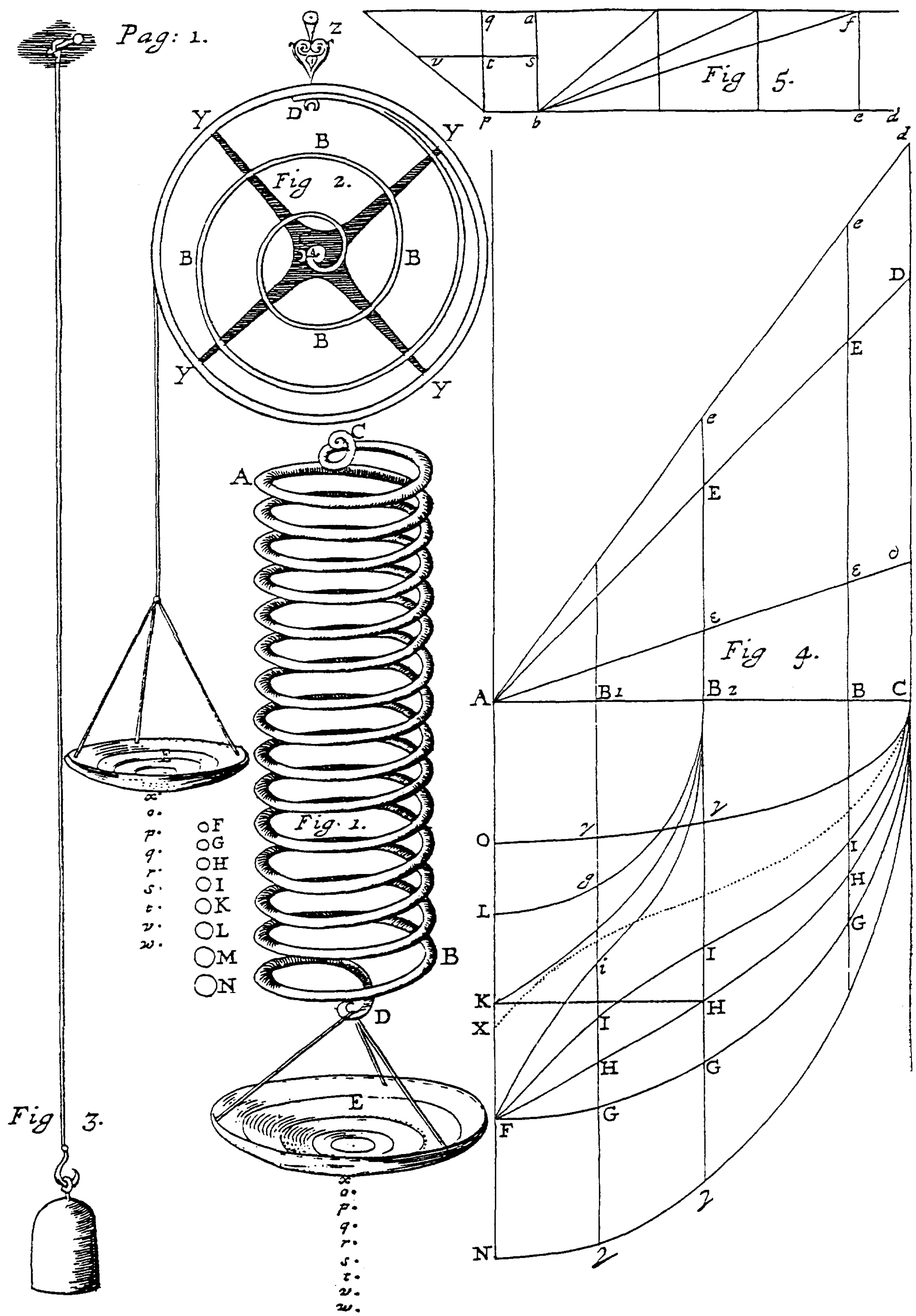
COLLECTIONS

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.


Pag: 1.
Fig 2.
Fig. 1.
Fig 3.
Fig 4.
Fig 5.

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 it 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 coyl 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 coyl 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 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 coyl 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 coyl 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 ſilk, 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, Glaſs, and the like. Reſpect being had to the particular figures of the bodies bended, and the advantagious or diſadvantagious ways of bending them.