SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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National Science Education Standard—Physical Science

Motions and Forces

Between any two charged particles, electric force is vastly greater than the gravitational force. Most observable forces such as those exerted by a coiled spring or friction may be traced to electric forces acting between atoms and molecules.

Teacher Materials

Learning Sequence Item:

921

Forces Acting on a Spring

March 1996
Adapted by: *Bill G. Aldridge*

Elastic and Frictional Forces: Electric Forces Between Atoms and Molecules. Students should observe and graph the relationship between the force acting on a spring and its extension. They should recognize that the force of the spring has a direction opposite to its extension or compression. (*Physics, A Framework for High School Science Education, p. 24.)*

Contents

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

921

Learning Sequence

Elastic and Frictional Forces: Electric Forces Between Atoms and Molecules. Students should observe and graph the relationship between the force acting on a spring and its extension. They should recognize that the force of the spring has a direction opposite to its extension or compression. *(Physics, A Framework for High School Science Education, p. 24.)*

Science as Inquiry	Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science
Springs and Things **Activity 1** Measuring Force and Stretch **Activity 2** Wires as Springs **Activity 3**	Things That Stretch **Assessment 2**	Car Springs **Assessment 1** Designing a Bungee **Assessment 3**	Explaining the Power of Springing Bodies (*Original observations by Robert Hooke*) **Reading 1**

Suggested Sequence of Events

Event #1

Lab Activity

1. Springs and Things

Event #2

Lab Activity

2. Measuring Force and Stretch

Event #3

Lab Activity

3. Wires as Springs

Event #4

Readings from Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science

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

Readings can be found in the student version of this publication.

Assessment items are at the back of this volume.

Assessment Recommendations

This teacher materials packet contains a few items suggested for classroom assessment. Often, three types of items are included. Some have been tested and reviewed, but not all.

1. Multiple-choice questions accompanied by short essays, called justification, that allow teachers to find out if students really understand their selections on the multiple choice.

2. Open-ended questions asking for essay responses.

3. Suggestions for performance tasks, usually including laboratory work, questions to be answered, data to be graphed and processed, and inferences to be made. Some tasks include proposals for student design of such tasks. These may sometimes closely resemble a good laboratory task, since the best types of laboratories are assessing student skills and performance at all times. Special assessment tasks will not be needed if measures such as questions, tabulations, graphs, calculations, etc., are incorporated into regular lab activities.

Teachers are encouraged to make changes in these items to suit their own classroom situations and to develop further items of their own, hopefully finding inspiration in the models we have provided. We hope you may consider adding your best items to our pool. We also will be very pleased to hear of proposed revisions to our items when you think they are needed.

Science as Inquiry

Springs and Things

How do things stretch?

Overview:

This activity is qualitative and observational. Students are just going to make careful observations when something elastic—rubber bands and springs—are stretched. They also consider the realtionship between force and distortion in a soccer ball and a metal ruler. In the next two activities students are led to consider the quantitative aspects of such "springs."

Materials:

Per student:
rubber bands of different thickness, 3 per student
springs, 3, each with a different spring constant
notebook

Per lab group:
soccer ball
metal ruler (thin)
clamp (to hold ruler to tabletop)

Procedure:

Have students hold one end of a rubber band and pull on the other end. Let them define as positive the direction that the rubber band stretches when pulled. Then let them determine what direction the force is that they exert on the rubber band when they stretch it. They should do the same set of observations for two or three other rubber bands of various thicknesses and determine qualitatively how the magnitude of the force required changes from rubber band to rubber band based upon thickness (or stiffness).

Have students draw illustrations in their notebooks, using arrows to show these forces and their directions. They should then repeat this simple experiment with several small springs, each having a different stiffness.

Finally, they should determine the direction of forces when they push down on a soccer ball held against the floor and when they pull up or push down on the free end of a metal ruler clamped to a tabletop.

Background:

This is a qualitative version of a classic experiment first conducted by Robert Hooke in the mid 1600s and published by him in 1678. The relevant pages from his original article are included with the student materials as an optional reading for some of your better students.

Adapted from: none

Science as Inquiry

Measuring Force and Stretch

How does the stretch of a spring relate to the force stretching it?

Overview:

In the previous activity students learned that the force exerted 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. They also learned qualitatively that the more a spring is stretched, the more force must be exerted. Here students measure the amount of stretch and the force needed to produce that amount.

Materials:

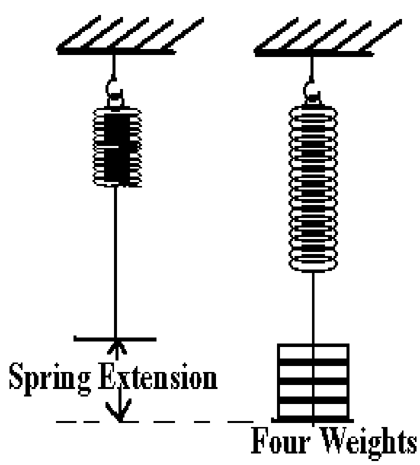
Per lab group:

springs, 2, each with a different spring constant
ring stand with supports to hold springs
weights and weight holders (50 g–100 g), 5–6
meter sticks
notebooks and graph paper

Procedure:

Have students use the ring stand, and clamps and supports to set up the experimental arrangement as shown. As they add weights the spring is extended, and they can measure that extension in centimeters. They should take measurements of extension for each added weight, from one to five or six total weights.

Students should then make a graph, with extension on the vertical axis and force in number of weights on the horizontal axis. They should do this for springs of two different stiffness.



Background:

The slope of the extension vs. force graph gives the spring constant. The stiffer the spring, the steeper the graph. Students need to see this general relationship. Note that at this level we are not using newtons for force. This can be done in grade 10 or grade 11, when again students will encounter Hooke's law in terms of oscillating masses and pendulum motion in studies of simple harmonic motion and waves.

Hooke's law is far more important than at first glance it might appear. The oscillation of objects about an equilibrium position occurs everywhere, and Hooke's law accounts for those oscillations. Because any force with any dependency can be expanded in a Taylor's series about some equilibrium position, a Hooke's law "spring" constant can be determined for such motion. From that knowledge, much can be understood. For example, the vibrational modes of two carbon atoms with a single bond in a diatomic molecule has a Hooke's law spring constant of 516 N/m, and from this information you can determine the infrared absorption frequency for that diatomic molecule.

Adapted from: none

Science as Inquiry

Wires as Springs

How does a wire stretch?

Overview:

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, students conduct their own experiment using a wire and weights.

Materials:

Per lab group:
steel wire (15–21 gauge), 8-ft length
protective glasses
weight holders and setup
weights (100 g), 5
metric rulers
notebooks and graph paper

Procedure:

Using a length of steel wire, students should fix one end of the wire to the ceiling of the classroom. They then 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. Then, as they add weights and stretch the wire they should record their measurements of number of weights per amount the wire is stretched.

To be sure that the wire has not been permanently distorted, have students remove weights one at a time, until they have removed them all. The wire, if it has not been permanently distorted, will revert to its original position, as measured from the floor to the weight holder.

Students will need help connecting the distance from the weight holder to the floor to the wire's extension. When they have this information, have them graph the extension vs. the force in weights, as they did with the springs. They should then find the slope, relate it to stiffness of the wire, and compare this spring constant with that of the springs. If they use the same units of force (same weight size), these numbers are comparable.

Background:

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 to which he makes reference is interesting. 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." Explain to students how he was able in this way to "publish" his work two years earlier, but without writing anything except the anagram. They might make up some simple anagrams themselves and try to use them.

When Hooke did his experiment with wire, it stretched like a spring, returning to its normal length when the weights were removed. You can refer students to that part of his paper to see exactly what he did. You also might point out the various kinds of springs that Hooke used in his experiments, those shown in the illustration that he created for his paper. Note that he made a spiral spring himself, and he tells how to do this.

Variations:

Students could observe the Hooke's law phenomenon with a variety of different things. For example, they could use nylon string.

Adapted from: none

Teacher Sheet

Science in Personal and
Social Perspectives

Car Springs

Item 1:

As you know, every automobile uses springs to help make the car ride better. If a car weighs 3,200 lb and has four coil springs, what should be the stiffness constant in lb/in for one of these springs if it is to be compressed no more than 4 inches by the weight of the car? (Assume that each spring must support one fourth of the weight of the car.)

Answer:

The car weighs 3,200 lb, so each spring must support 3,200 lb/4 = 800 lb. Since 800 lb can compress the car by no more than 4 inches, the spring constant must be 800 lb/4 in = 200 lb/in.

Item 2:

Suppose that a person sits on the fender of a car and the car is pushed downward two inches. If the person weighs 120 lb and you assume that all of this weight is used to compress the car spring directly under that fender, what is the spring constant? If this is the spring constant, then how much will that spring be extended if you lift the weight of the car off of it? Assume the car has a weight of 2,400 lb, so that 600 lb is compressing the spring.

Answer:

If 120 lb compresses the spring 2 inches, then the constant must be 120 lb/2 in = 60 lb/in. If you lift the car's weight off this spring, and force = spring constant × extension, then 600 lb = 60 lb/in × extension, or extension = 10 in. The spring would extend 10 inches more than when it was compressed by the weight of the car.

Teacher Sheet

Science and Technology

Things That Stretch

Item:

A large, thick rubber strip made into a catapult requires 200 lb to stretch it 5 inches. If this catapult is stretched backward 40 inches, how much force will it deliver initially to a 5-lb steel ball?

Answer:

The force required to stretch this catapult per inch must be 200 lb/5 in = 40 lb/in. If the rubber strip made into a catapult is stretched 40 inches, then the force must be 40 in × 40 lb/in or 1600 lb of force initially acting upon the 5-lb steel ball. That should give it quite a boost!

Teacher Sheet

Science in Personal and
Social Perspectives

Designing a Bungee

Item:

1. Design an investigation to compare materials used for constructing a bungee.

2. Suggest ways to build a better bungee.

3. Considering the safety of this sport, are there any hidden dangers?

4. Should age be a factor in this sport?

5. Should the government control the laws of this sport?

Consumables

Item	Quantity per lab group	Activity
graph paper	—	2, 3
notebooks	—	1, 2, 3
rubber bands of different thickness	3 per student	1

Nonconsumables

Item	Quantity per lab group	Activity
metal ruler	1	1
meter stick	1	2
metric ruler	1	3
protective glasses	—	3
ring stand with supports to hold springs	1	2
soccer ball	1	1
springs (of different spring constants)	3 per student	1
springs (of different spring constants)	2	2
steel wire (15–21 gauge)	1 8-ft length	3
weights and weight holders (50 g—100 g)	5–6	2
weights and weight holders (100 g)	5	3

Key to activities:

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