Bell Ringer: Determining a Spring Constant – ID: 13432

Based on an activity by Irina Lyublinskaya

Time required
15 minutes

Topic: Force and Motion

- *Determine a spring constant.*

Activity Overview

In this activity, students use a simulation of a spring to explore the relationship between displacement and restoring force. They use a graph of force vs. displacement to determine the spring constant for the simulated spring.

Materials

To complete this activity, each student will require the following:

- *TI-Nspire™ technology*
- *pen or pencil*
- *blank paper*

TI-Nspire Applications

Graphs & Geometry, Notes

Teacher Preparation

Before carrying out this activity, you should review with students the concept of static equilibrium.

- *The screenshots on pages 2–4 demonstrate expected student results. Refer to the screenshots on page 5 for a preview of the student TI-Nspire document (.tns file). The solution .tns file contains data analysis and answers to the questions.*
- ***To download the student .tns file and solution .tns file, go to education.ti.com/exchange and enter "13432" in the search box.***
- *For a more extensive exploration of this content, use activity 9901: Spring Constant. Activity 9901, which is longer than this bell ringer and involves data collection and analysis by the students, was designed for a full class period. You can download the files for activity 9901 at education.ti.com/exchange.*

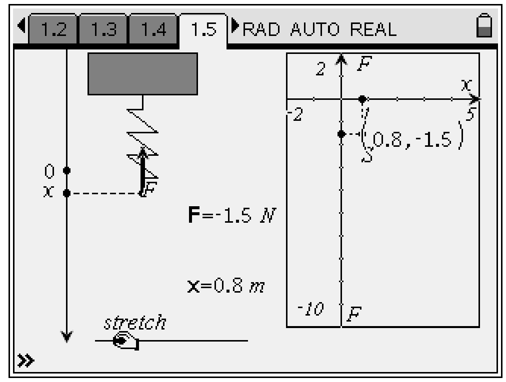
Classroom Management

- *This activity is designed to be* ***student-centered****, with the students working cooperatively. However, you will need to guide students through the steps of the activity.*
- *If you wish, you may modify this document for use as a student worksheet. You may also wish to use an overhead projector and TI-Nspire computer software to demonstrate the use of the TI-Nspire to students.*
- *If students do not have sufficient time to complete the questions, they may also be completed as homework.*
- *In some cases, these instructions are specific to those students using TI-Nspire handheld devices, but the activity can easily be done using TI-Nspire computer software.*

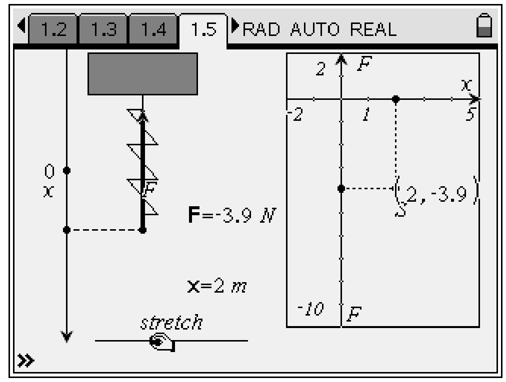
The following question will guide student exploration during this activity:

- How can the spring constant for a spring be calculated from displacement and restoring force data?

Students use a simulated spring to explore how the restoring force changes as the displacement of the spring changes. They determine the mathematical function relating displacement and restoring force. They use this equation to calculate the spring constant for the simulated spring.



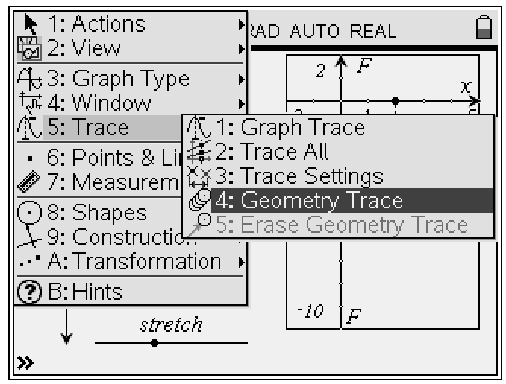
Step 1: Students should open the file **PhysBR_week09_det_spr_const.tns**, read the first four pages, and then move to page 1.5. Page 1.5 shows a simulated spring hanging vertically. The spring's weight pulls it downward, and its restoring force pulls it upward in response. When the two forces are balanced, the spring does not move. This is the situation first shown on page 1.5: the spring is in equilibrium. The *stretch* slider can be used to stretch the spring past its equilibrium point. As the spring is stretched, it exerts a restoring force upward. This force is calculated using the equation $F = -kx$, where k = 2 N/m. Point *S* on the graph on the right shows the displacement and restoring force for the spring at any given point. The displacement (x) is shown on the x-axis of the graph on the page, and the force is shown on the y-axis. Thus, point *S* has coordinates (x, F). (The x-axis is also shown, vertically, on the simulation diagram for reference.) Students should use the *stretch* slider to change the stretch of the spring and observe the effect of the stretch on the restoring force. Students can observe the physical stretching of the spring, the change in the magnitude of the restoring force vector, and the movement of point *S* on the graph as they vary the displacement (stretch) of the spring. The stretch values range from 0 m to 5 m. The range of values for force is 0 N to 10 N.



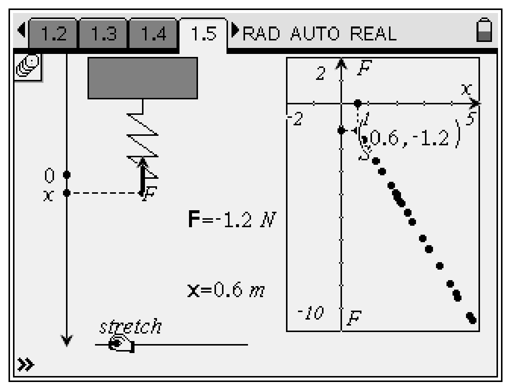
Step 2: Once students have explored the simulation, they should answer question 1.

Q1. Describe the relationship between the stretch (displacement) of the spring and the magnitude and direction of the restoring force.

A. *The restoring force is always opposite in direction to the spring's displacement, and the magnitude of the force is directly proportional to the magnitude of the displacement.*



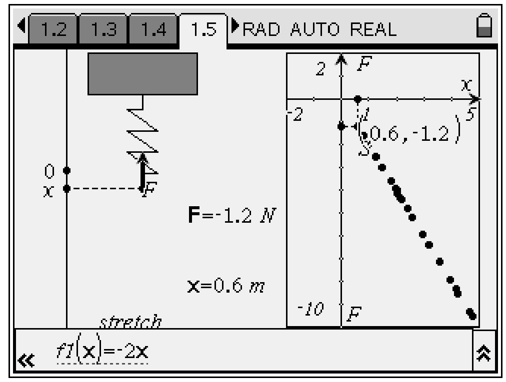
Step 3: Next, students should move back to page 1.5. They should use the **Geometry Trace** tool (**Menu > Trace > Geometry Trace**) to put a trace on point *S* in the graph on page 1.5. To use the **Geometry Trace** tool, students should first select it from the menu. They should then click once (press [click]) on point *S*. After students have selected point *S*, they should use the NavPad to move the cursor until it is above the point on the *stretch* slider. They should press [ctrl][click] to grab the point and drag it along the slider. As they drag the point, the various positions of point *S* should be marked on the graph. They should move the *stretch* point and observe the shape of the trace. Note: Make sure students do not press [esc] after selecting point *S* with the **Geometry Trace** tool. After they have observed the trace for a variety of different points, they should answer question 2.

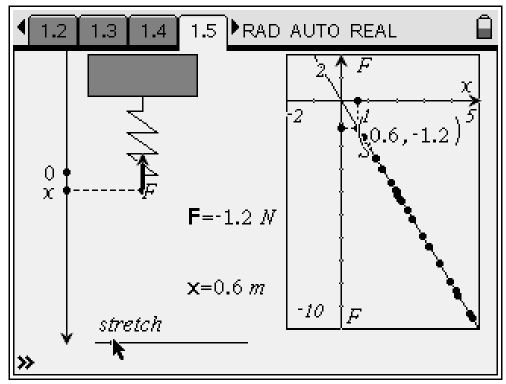


Q2. What type of mathematical relationship does there appear to be between *x* and *F*? That is, what equation of the form *F*(*x*) appears to describe the locations of point *S* as the string is stretched?

A. *Based on the geometry trace and observed values of* F *and* x, *students should be able to determine that the equation F(x) = –2x fits the data on the location of point* S.

Step 3: Next, students should move back to page 1.5. They should press ctrl G to show the formula line for the *Graphs & Geometry* page. They should enter the equation for the function they identified in question 2. (For example, if students thought the trace of point *S* lay along a line with equation *F*(*x*) = –3*x*, they should enter that equation in the equation line.) When they have entered their equation, they should press enter to graph the function. They should study the graph to determine whether their inferred equation was correct. If it was not, they should modify the equation until it fits the data. To modify the equation, students should again press ctrl G to show the equation line. They should press ▲ on the NavPad to move to equation *f1*(*x*) and then type in the new equation. They should then answer question 3.





Q3. Plot your mathematical relation on page 1.5. Was your inferred equation correct? If not, explain any errors in your reasoning.

A. *Students' answers will vary. Encourage students to think critically about their reasoning and identify any invalid assumptions or inferences they made.*

Step 3: Next, students should read the text on page 1.9, which defines the spring constant. They should again study the graph on page 1.5 and then answer questions 4 and 5.

Q4. What are the units for the spring constant? Explain your answer.

A. *The units of the spring constant are newtons per meter (N/m). These units follow from the general equation for Hooke's law: F = –kx, where* F *is in newtons and* x *is in meters.*

Q5. What is the spring constant for the spring on page 1.5?

A. *The equation relating force and displacement for this spring is F(x) = –2x, so the spring constant is 2 N/m.*

Suggestions for Extension Activities: If you wish, you may have students measure the actual spring constants for several real springs by adding known weights to them and measuring their displacements. Alternatively, you can give students springs with known spring constants and have them predict displacement for a given weight. They can then test their predictions.

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(Student)TI-Nspire File: *PhysBR_week09_det_spr_const.tns*

1.1 DEG AUTO REAL

DETERMINING A SPRING CONSTANT

Physics

Hooke's Law

1.2 DEG AUTO REAL

Consider a uniform, coiled spring hanging vertically. If the spring is stretched or compressed, the spring exerts a force that acts in the direction opposite to the displacement. The force exerted by the spring is called the *restoring force*. When the forces acting on the spring are balanced, the spring is at rest in an equilibrium position.

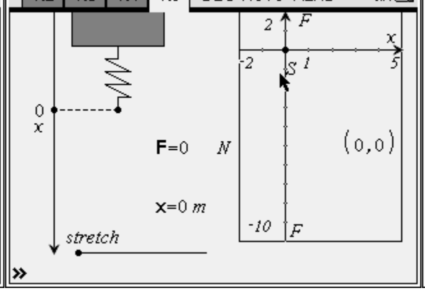
1.3 DEG AUTO REAL

When the spring is stretched or compressed, the restoring force acts in the direction opposite the displacement, acting to return the spring to its equilibrium position. The relationship between the magnitude of the restoring force and the magnitude of the displacement of the spring from its equilibrium position is known as *Hooke's law.*

1.4 DEG AUTO REAL

The next page shows a coiled spring hanging vertically. Explore the relationship between the restoring force of the spring, *F*, and the amount of stretch, *x*. Use the *stretch* slider to change the amount of stretch (displacement from equilibrium), and observe the changes in the magnitude of the restoring force.

1.5 DEG AUTO REAL



1.6 DEG AUTO REAL

1. Describe the relationship between the stretch (displacement) of the spring and the magnitude and direction of the restoring force.

1.7 DEG AUTO REAL

2. What type of mathematical relationship does there appear to be between *x* and *F*? That is, what equation of the form $F(x)$ appears to describe the locations of point *S* as the string is stretched?

1.8 DEG AUTO REAL

3. Plot your mathematical relation on page 1.5. Was your inferred equation correct? If not, explain any errors in your reasoning.

1.9 DEG AUTO REAL

The constant of proportionality between displacement and restoring force is known as the spring constant. By convention, the spring constant is a positive number.

1.10 DEG AUTO REAL

4. What are the units for the spring constant? Explain your answer.

1.11 DEG AUTO REAL

5. What is the spring constant for the spring on page 1.5?

