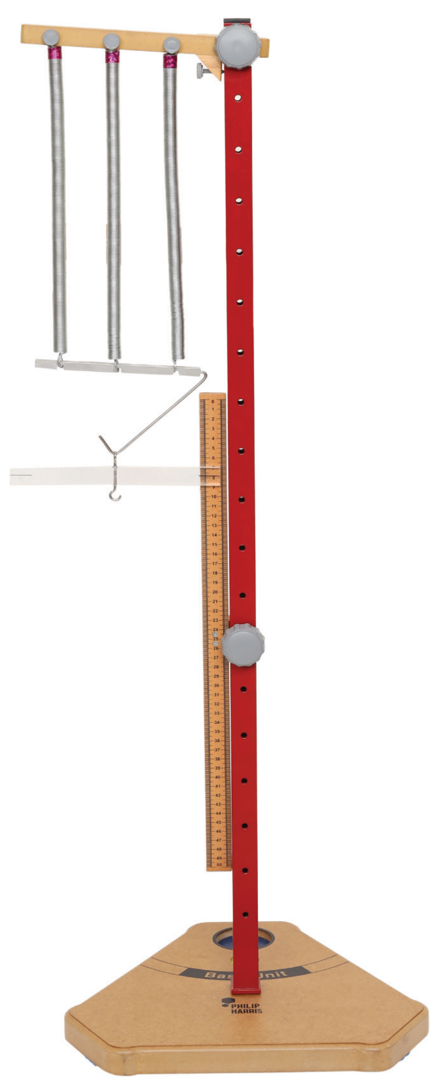
Foundation Physics



Hooke's Law

Hooke's Law

KIT CONTENTS

ITEM	QUANTITY	DESCRIPTION
1	3	Short springs (15 cm)
2	3	Long springs (30 cm) marked magenta
3	1	Long spring (30 cm) marked green
4	1	Long spring (30 cm) marked blue
5	1	Triangle connector
6	1	Clear plastic reading bar
7	1	Mass hanger
8	1	Instructions (this booklet): Teacher's Guide: pages 2 - 10 Student Activity Sheets (reproducible): pages 11 - 27

Additional Materials needed:
Foundation Physics
Meter stick
Spring scales

OVERVIEW / SUGGESTIONS FOR USE

Hooke's Law is versatile and allows investigations into various characteristics of spring motion. Using various springs, students investigate extension, tension, oscillation, springs in series and springs in parallel. Students also calculate the mass of an object using the period of a spring.

CLASS TIME REQUIRED

30 - 45 minutes per lab activity

GRADE LEVEL

7 - 13

NATIONAL CURRICULUM STANDARDS

Content Standards	Grades 7-12
A. Working Scientifically	• Development of Scientific thinking • Apply mathematical concepts and calulate results
B. Physics	• Motion and forces • Conservation / transfer of energy

SAFETY

Students should wear safety goggles during all activities to prevent eye injuries from springs or rubber bands. Students should also keep feet and other body parts out from beneath the hanging masses to prevent injury should the spring or rubber band break and the masses fall.

TEACHER PREPARATION (PRIOR TO CLASS)

Set up the apparatus in a clear area. One apparatus will accommodate a group of 4 - 5 students.
Read through the Teacher's Guide and Student Guide. Make copies of page S1 - S23 for the students.

TEACHING ACTIVITY SUGGESTIONS

Extension activities are provided in the student guide at the end of several of the activities listed below.

Activity 1. Stretching Springs (Student Guide pages 11 - 13) - KS3 and KS4
Students will investigate how different springs have different spring constants.
Students will determine the spring constants of various springs.

Activity 2. Stretching a Spring (Student Guide pages 14 - 17) - KS3 and KS4
Students will investigate the behavior of a spring over its normal range of motion and investigate the stretching of two different springs and compare the results.

Activity 3. Springs in Series (Student Guide pages 22 - 25) - A-Level
Students will investigate springs in series.
Students will determine the spring constant of springs in series and how it relates to the spring constants of the individual springs.

Activity 4. Springs in Parallel (Student Guide pages 26 - 29) - A-Level
Students will investigate springs in parallel.
Students will determine the spring constant of springs in parallel and how it relates to the spring constants of the individual springs.

Activity 5. Spring Oscillations (Student Guide pages 30 - 31) - A-Level
Students will predict the period of oscillation and compare their predictions to actual results.

TEACHER GUIDE ANSWER KEY

ACTIVITY 1. STRETCHING SPRINGS

Procedure:

The procedure for this activity is explained to the students on page S2 of the Student Guide. For steps 5 and 10, the "Applied Force" (N) is calculated by multiplying the mass (kg) by the force of gravity (9.8 m/s²).

Data Table 1: Sample Data

Spring (color)	Applied Mass (kg)	Applied Force (N)	Extension (m)	Spring Constant (N/m)
Magenta	*1.0*	*9.8*	*0.145*	*67.6*
Blue	*1.0*	*9.8*	*0.170*	*57.6*
Green	*1.0*	*9.8*	*0.045*	*217.8*
Short	*0.40*	*3.9*	*0.290*	*13.4*

ACTIVITY 1. STRETCHING SPRINGS (continued)

Questions:

1. List the springs in order, starting with the one that stretches most easily to the one that is hardest to stretch.
   Short, green, magenta, blue
2. How is the "stretchiness" of the spring related to its spring constant?
   As stretchiness decreases, spring constant increases.
3. Get a spring scale that reads up to 5 Newtons. Examine the way it is constructed, paying particular attention to the spring and the measuring scale printed along the tube. Draw a diagram of the spring scale and use it to help explain how the spring scale can be used to measure forces up to 5 Newtons.
   The spring is at equilibrium (there is no tension) when force is zero.
4. Explain why the 5-Newton spring scale has a "stop" that prevents it from measuring forces much larger than 5 Newtons.
   The spring in the spring scale will not return to equilibrium after 5 N; it will be too stretched out.
5. Explain how you would design a spring scale to measure forces that are larger than 5 Newtons. After you have done this, ask your teacher for a spring scale that measures up to 10 (or 20) Newtons to see how your solution compares.
   Answers may vary but should mention using a spring with a greater spring constant than the one used in the 5 Newton spring scale.
6. The 5-Newton spring scale does not do a very good job of measuring forces smaller than 1 Newton. Explain how you would design a spring scale to measure forces that were much smaller than 1 Newton. Compare your solution with a spring scale that reads forces up to a maximum of 1 Newton.
   Answers may vary but should mention using a spring with a smaller spring constant than the one used in the 5 Newton spring scale.

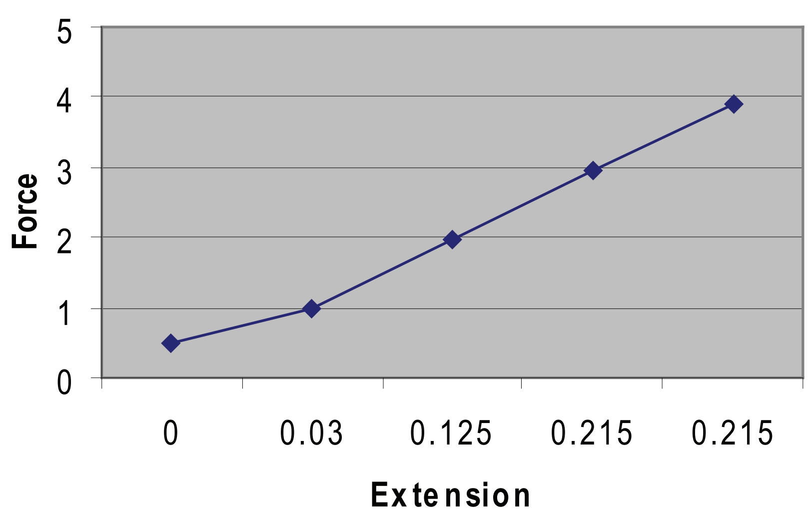
ACTIVITY 2. STRETCHING A SPRING

Procedure:

The procedure for this activity is explained to the students on pages S4 - S6 of the Student Guide. The clear plastic reading bar can be used to aid in measuring the extension of each spring by attaching it between the mass and the mass hanger. The reading bar can be used on only one spring at a time.

Data Table 2: Sample Data

Trial	Applied Mass (kg)	Applied Force (N)	Extension (m)
1	*0.05*	*0.49*	*0.00*
2	*0.10*	*0.98*	*0.03*
3	*0.20*	*1.96*	*0.125*
4	*0.30*	*2.94*	*0.215*
5	*0.40*	*3.92*	*0.215*

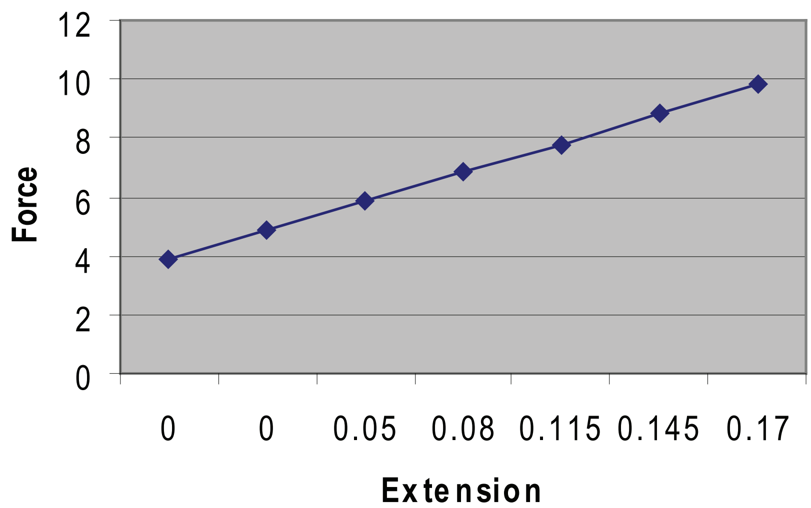


ACTIVITY 2: STRETCHING A SPRING (continued)

5. Find the slope of the line in Newtons per meter (N/m) by dividing rise over run.
   Slope for the small spring is 13.5 N/m.

Data Table 3: Sample Data

Trial	Applied Mass (kg)	Applied Force (N)	Extension (m)
1	*0.40*	*3.9*	*0*
2	*0.50*	*4.9*	*0*
3	*0.60*	*5.9*	*0.05*
4	*0.70*	*6.9*	*0.08*
5	*0.80*	*7.8*	*0.115*
6	*0.90*	*8.8*	*0.145*
7	*1.0*	*9.8*	*0.17*



10. Find the slope of the line in Newtons per meter (N/m) by dividing rise over run.
    Slope for the large spring is 33 N/m.

Questions:

1. How would you describe the relationship of the data points for each of the springs?
   The relationship is linear.
2. In what way are the two springs similar? In what way are the two springs different?
   Similar material, construction; different lengths, thickness of metal, diameter of coils
3. Compare the values of the slopes with the values of the spring constants you found earlier.
   Ex. For the green spring: Activity 1- 57.6 N/m, Activity 2- 32.5 N/m.
4. Which value of the spring constant (one found from single measurements or one found from the slope) do you think more accurately describes the overall behavior of a spring? Explain your answer.
   Activity 2 is probably a more trustworthy experiment because it uses more data points and eliminates random error.
5. If one Newton of force is applied to one of the springs when it is not stretched very much, does it produce a different stretch than if an extra Newton of force were added when it is stretched more? Explain how the graph supports and confirms this idea.
   Yes, the more stretched the spring is, the more stretched it will be by 1 N. Ex: For the green spring at equilibrium, it didn't stretch until the force reached 6 N. After that point, 1 N stretched the spring considerably. That explains why the plot in the graph didn't begin an upward slope until 6 N.
6. Draw a picture and describe how these springs could be made into spring scales. Which spring would be used for measuring the largest forces?
   Answers may vary.
7. How would you change the spring scale you described to measure mass?
   Answers may vary.

ACTIVITY 3: TENSION

Procedure:

Part 1: **Stretching a Spring Horizontally**

The procedure for this activity is explained to the students on page S9 of the Student Guide.

Questions

1. When you compare the spacing of the coils in all three situations, can you detect any significant difference in the way the springs stretched?
   The weaker springs will have a more significant stretch to them as compared to the stronger springs when the same force is applied.
2. When your hand is replaced with a spring scale, does it make any difference in the length of the spring or the reading on the other spring scale?
   No.
3. When two identical springs are pulled in line with each other, how do their stretched lengths compare?
   Same.
4. If you thought of these two springs as a single spring, how does the extension (total stretch) of this spring compare to the extension of a single short spring?
   Same.

Procedure:

Part 2: Stretching a Spring Vertically

The procedure for this activity is explained to the students on page S10 of the Student Guide. Measure out the string for this activity (5 cm - 20 cm) so that the masses do not hit the table or the Foundations of Physics stand.

Questions

1. Does the length of the string have any effect on the reading of the spring scale?
   No.
2. Does the tension in the string depend on the length of the string?
   No.
3. How do the tensions at different distances along a stretched string compare?
   Same.
4. Does the amount of stretch in any of the components depend on where it is located in the line or how many other components are in the series? Explain why this makes sense.
   No. There is only one mass and, therefore, one source of force. The force is evenly distributed across the line.

ACTIVITY 4: SPRINGS IN SERIES

Procedure:

The procedure for this activity is explained to the students on page S12 of the Student Guide.

Data Table 4: Sample Data

Trial	Applied Mass (kg)	Applied Force (N)	Extension (m)
1	*0.05*	*0.49*	*0.00*
2	*0.10*	*0.98*	*0.03*
3	*0.20*	*1.96*	*0.125*
4	*0.30*	*2.94*	*0.215*
5	*0.40*	*3.92*	*0.215*

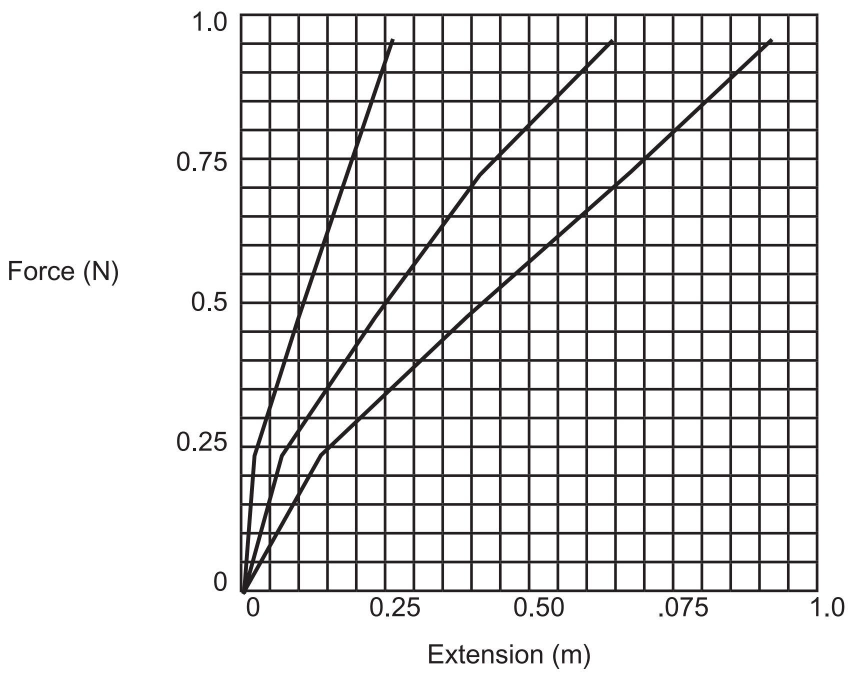
Data Table 5: Sample Data

Trial	Applied Mass (kg)	Applied Force (N)	Extension (m)
1	*0.10*	*0.98*	*0.07*
2	*0.20*	*1.96*	*0.24*
3	*0.30*	*2.94*	*0.415*
4	*0.40*	*3.92*	*0.415*

ACTIVITY 4. SPRINGS IN SERIES (continued)

Data Table 6: Sample Data

Trial	Applied Mass (kg)	Applied Force (N)	Extension (m)
1	*0.04*	*0.392*	*0.035*
2	*0.08*	*0.784*	*0.115*
3	*0.10*	*0.980*	*0.155*
4	*0.12*	*1.176*	*0.220*
5	*0.14*	*1.372*	*0.270*



7. The slope for the three lines may vary, but they should be close to the values below:

Slope for one spring in series: *13 N/m*

Slope for two springs in series: *6.3 N/m*

Slope for three springs in series: *4.0 N/m*

Questions

1. In what way are the three springs similar? In what way are the three springs different?
   Answers may vary.
2. How would you describe the relationship of the data points for each of these springs?
   The relationship is linear.
3. Compare the values of the slopes to each other. These slopes are definitely related to each other in a simple way. What is this relationship and why does it make sense?
   The slope decreases as number of springs in series increases. The series of springs, which can be considered one spring, become “stretchier” as more springs are added.

ACTIVITY 5: SPRINGS IN PARALLEL

Procedure:
The procedure for this activity is explained to the students on page S16 of the Student Guide.

Data Table 7: Sample Data

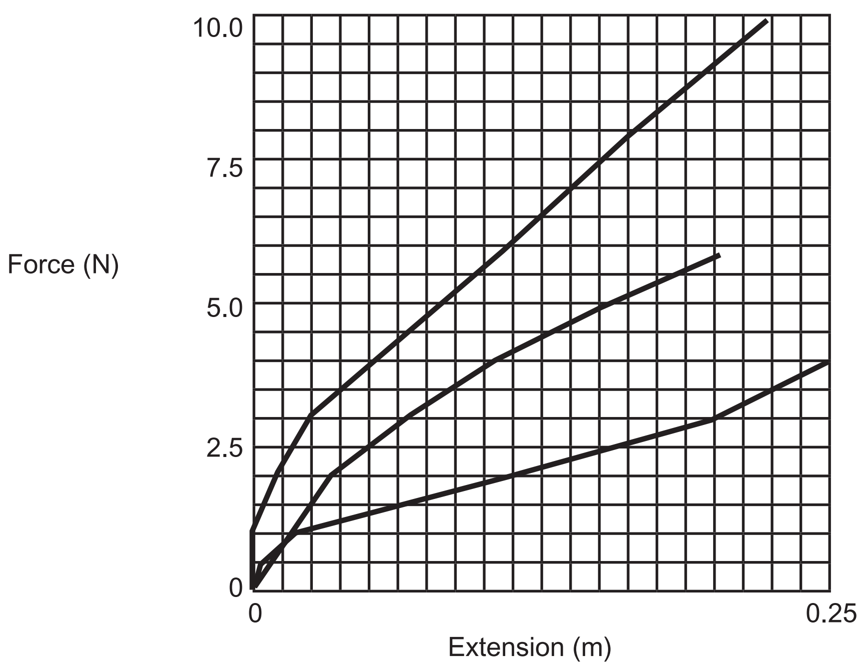
Trial	Applied Mass (kg)	Applied Force (N)	Extension (m)
1	*0.05*	*0.49*	*0.00*
2	*0.10*	*0.98*	*0.03*
3	*0.20*	*1.96*	*0.125*
4	*0.30*	*2.94*	*0.215*
5	*0.40*	*3.92*	*0.28*

Data Table 8: Sample Data

Trial	Applied Mass (kg)	Applied Force (N)	Extension (m)
1	*0.20*	*1.96*	*0.04*
2	*0.30*	*2.94*	*0.085*
3	*0.40*	*3.92*	*0.13*
4	*0.50*	*4.9*	*0.17*
5	*0.60*	*5.88*	*0.21*

Data Table 9: Sample Data

Trial	Applied Mass (kg)	Applied Force (N)	Extension (m)
1	*0.10*	*0.980*	*0.00*
2	*0.20*	*1.96*	*0.01*
3	*0.40*	*3.92*	*0.065*
4	*0.60*	*5.88*	*0.12*
5	*0.80*	*7.84*	*0.18*
6	*1.0*	*9.8*	*0.24*



ACTIVITY 5. SPRINGS IN PARALLEL (continued)

Questions

1. When additional springs are placed in parallel, is the combination harder or easier to stretch than fewer springs? Explain why you think this makes sense.
   It becomes harder to stretch the springs as more are added in parallel. This is because it is like making the wire of the spring thicker and heavier.
2. If one spring is harder to stretch than another, does it have a larger or smaller spring constant?
   The harder it is to stretch, the larger the spring constant.
3. How would you describe the relationship of the data points for each of these springs?
   The relationship is linear.
4. Compare the values of the slopes to each other. These slopes are definitely related to each other in a simple way. What is this relationship and why does it make sense?
   The slope is multiplied by the number of springs. Two springs in parallel have double the slope; three springs in parallel have triple the slope.

ACTIVITY 6: SPRING OSCILLATIONS

Procedure:

The procedure for this activity is explained to the students on pages S20 and S21 of the Student Guide.

Data Table 10: Sample Data

Spring (color)	Spring Constant (k) (N/m)	Time for 10 vibrations (s)	Period (T) (s)
Green	*57.6*	*8.56*	*0.856*
Magenta	*67.6*	*7.68*	*0.768*
Blue	*217.8*	*4.35*	*0.435*
Short	*13.4*	*11.935*	*1.194*

Questions

1. How does the period of vibration differ for the three springs?
   As force constant increases, T decreases.
2. What things are the same for these three springs?
   Answers may vary.

ACTIVITY 7: USING THE PERIOD OF A SPRING TO MEASURE MASS

Procedure:
The procedure for this activity is explained to the students on page S22 of the Student Guide.

Data Table 11: Sample Data

Spring (color)	Spring Constant (k) (N/m)	Period (T) (s)	Calculated Mass (g)	Actual Mass (g)
Green	*57.6*	*0.856*	*1,071*	*1,000*
Magenta	*67.6*	*0.768*	*1,011*	*1,000*
Blue	*217.8*	*0.435*	*1,046*	*1,000*

Questions
1. If you wanted to measure the masses of these objects by a different method, what would you do?
   You could use a mass of known density and use water displacement to find mass. Answers may vary.
2. Do this for your unknown objects and compare with the other values.
   Answers may vary.
3. Calculate the percent error of your calculated value for the unknown masses.
   Answers may vary.

Hooke’s Law — Student Guide

ACTIVITY 1: STRETCHING SPRINGS

Background:

Springs are found all around us but they are often hidden in the mechanism of a mechanical device. Therefore, you have to take the machine apart to see the springs. Just to make things interesting, these springs are often under tension in the device so that if you do take it apart, the springs fly out, and the device is difficult or impossible to reassemble.

Springs come in many forms. Coil springs are the form that will be used in most of these activities. Coil springs can be found in ball point pen mechanisms, bouncing baby seats, mouse traps, motors, and the suspension systems of cars. Leaf springs are another form and are also found in car suspensions. Mechanical toys often have springs made of flat metal wound in a flat coil. Bungee cords are springs; the stretching is due to stretching rubber, which is really the invisible uncoiling of rubber molecules. All of these springs obey the same simple law of stretching. The coil springs used in these activities are large enough that the extensions can be easily measured and that they act uniformly over a reasonable range.

Springs are described most simply in terms of how much force (Newtons) is needed to stretch them 1 meter. This number is called the “spring constant” and is given the symbol “k”. This has units of N/m and is part of the equation below. Just as you don’t have to travel 60 miles to clock a speed of 60 miles per hour, it isn’t necessary to stretch a spring 1 meter in order to measure its spring constant. The spring constant can be calculated from the individual values of force and extension by dividing the force value in Newtons by the extension value in meters. The spring constant is best found from the slope of a force/extension graph. This can be written in equation form, where k is the spring constant, F is the applied force, and x is the extension:

$$k = F/x$$

Often the equation will be written as a product rather than as a quotient:

$$F = kx$$

In most textbooks, the equation has a minus sign and is written $F = -kx$. If the spring is given an extension downward, the spring is pulling upward, in the opposite, or negative direction. While this is a more precise way to write the equation, it is a distinction that will not be important here, so we will keep everything positive.

This equation is an empirical statement about the behavior of springs. Empirical means that the equation states what is observed and is not the result of a theory. Because of this, the equation is only approximately true for real springs, and becomes absolutely untrue if the spring is quite stretched. The “quite stretched” condition is called the “elastic limit” of the spring. You might think that a law that is only approximately true would not be very useful or scientific. Just the opposite is true. Because this law describes the real behavior of real objects, it is used so often that it is given a name: Hooke’s Law. It is named after the 17th century English scientist, Robert Hooke, who first stated the law. Some of the most useful laws of science are this kind of “not absolutely true” variety.

Objectives:
- To acknowledge that different springs have different spring constants.
- To determine the spring constants of various springs.

Materials Needed:
Foundations of Physics Universal Stand
1 short spring (15 cm)
1 spring marked with magenta tape (30 cm)
1 spring marked with green tape (30 cm)
1 spring marked with blue tape (30 cm)
Metric ruler or meter stick
Clear plastic “reading bar”
Mass hanger
Various masses (400 g, 1 kg)
Various spring scales (5 Newton, 10 Newton, 1 Newton)

Procedure:
1. Place each colored spring into the holding bracket as shown in **Figure S1**.
2. To attach a spring to the holding bracket, unscrew one of the holding screws of the holding bracket and insert the metal ring of the spring into the wooden slot on the bottom of the bracket. Hold the ring in place and tighten the holding screw.
3. Record the color of each spring in the first column of **Data Table 1**.
4. Hang a 1.0-kg mass from each spring. Record this as “Applied Mass” in **Data Table 1**.
5. Record 9.8 Newtons in the “Applied Force” column of **Data Table 1**. (1 kg x 9.8 m/s^2)
6. Measure the distance that each spring stretches in meters and record the distance as “Extension” in **Data Table 1**. Note: Check that the half-meter stick is set so that the extension of each spring can be measured when mass is added to the end. A clear plastic “reading bar” is supplied with the materials to aid in this process.
7. Calculate the spring constant (k) for each spring. Divide the force applied to the spring by the distance of the extension of the spring and enter the quotient in **Data Table 1.**
8. Remove one of the other springs from the holding bracket and insert the short spring.
9. When using the short spring, do not use a 1-kg mass. The spring stretches easily and 1 kg is too much mass to add. Hang a 400-g mass from the spring, convert to kg and record this as “Applied Mass” in **Data Table 1**.
10. Record 3.9 Newtons in the “Applied Force” column of **Data Table 1**. (0.4 kg x 9.8 m/s^2)
11. Measure the distance that the spring stretches and record the distance in meters as “Extension” in **Data Table 1**. Note: You may need to reposition the meter stick so that the extension can be measured.

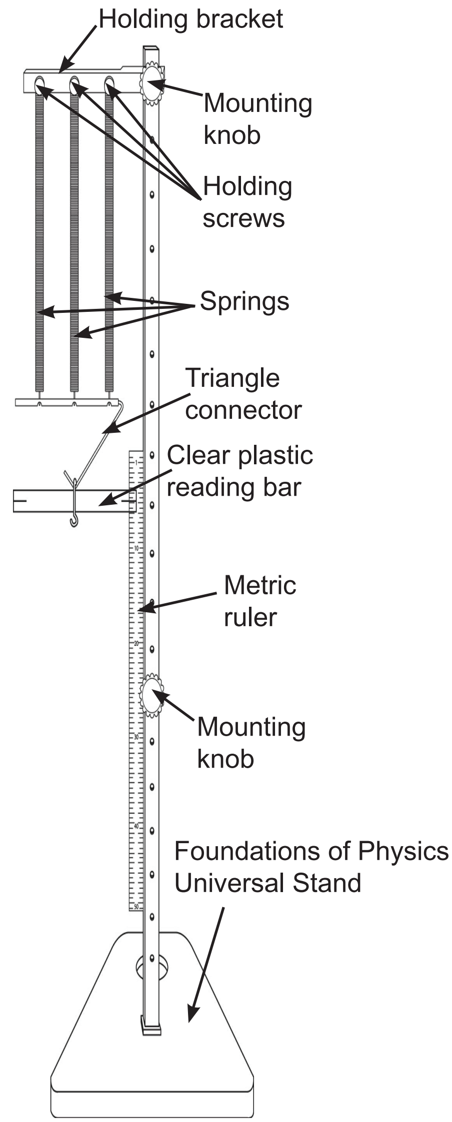


Figure S1

Data Table 1

Spring (color)	Applied Mass (kg)	Applied Force (N)	Extension (m)	Spring Constant (N/m)

Questions:

1. List the springs in order, starting with the one that stretches most easily to the one that is hardest to stretch.

2. How is the “stretchiness” of the spring related to its spring constant?

3. Obtain a spring scale that reads up to 5 Newtons. Examine the way it is constructed, paying particular attention to the spring and the measuring scale printed along the tube. Draw a diagram of the spring scale and use it to help explain how the spring scale can be used to measure forces up to 5 Newtons.

4. Explain why the 5-Newton spring scale has a “stop” that prevents it from measuring forces much larger than 5 Newtons.

5. Explain how you would design a spring scale to measure forces that are larger than 5 Newtons. After you have done this, ask your teacher for a spring scale that measures up to 10 (or 20) Newtons to see how your solution compares.

6. The 5-Newton spring scale does not do a very good job of measuring forces smaller than 1 Newton. Explain how you would design a spring scale to measure forces that were much smaller than 1 Newton. Compare your solution with a spring scale that reads forces up to a maximum of 1 Newton.

ACTIVITY 2: STRETCHING A SPRING

Background:
As you saw in the previous activity, different springs stretch differently when force or weight is applied to them, and this difference can be described with a number called the spring constant (k). An individual spring can be stretched a little or a lot. In this activity, you will investigate how an individual spring behaves over an extended range. That is, if a force is applied when the spring is stretched just a little, will the spring behave in the same way if this same force is applied when the spring is stretched more? Another way of asking this question is: “Does a spring behave uniformly over its normal range of motion?”

Objective:

- To determine the behavior of a spring over its normal range of motion.
- To investigate the stretching of two different springs and compare the results.

Materials Needed:
Foundations of Physics Universal Stand
1 short spring (15 cm)
1 long spring (30 cm)
Metric ruler or meter stick
Clear plastic “reading bar”
Mass hanger
Various masses (50 g, 100 g, 200 g, 300 g, 400 g, 500 g, 1 kg)

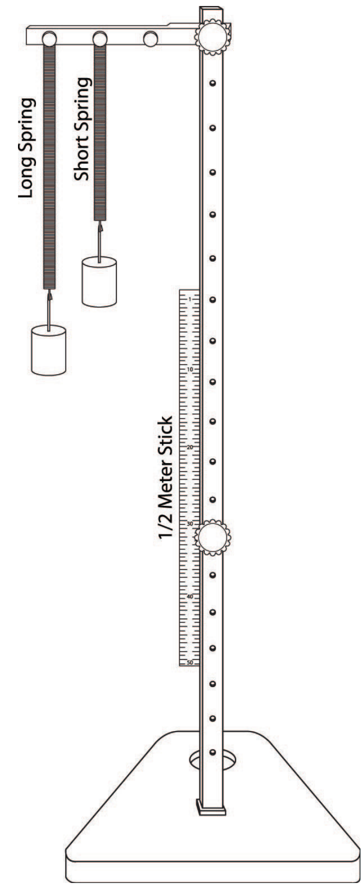


Figure S2

Procedure:

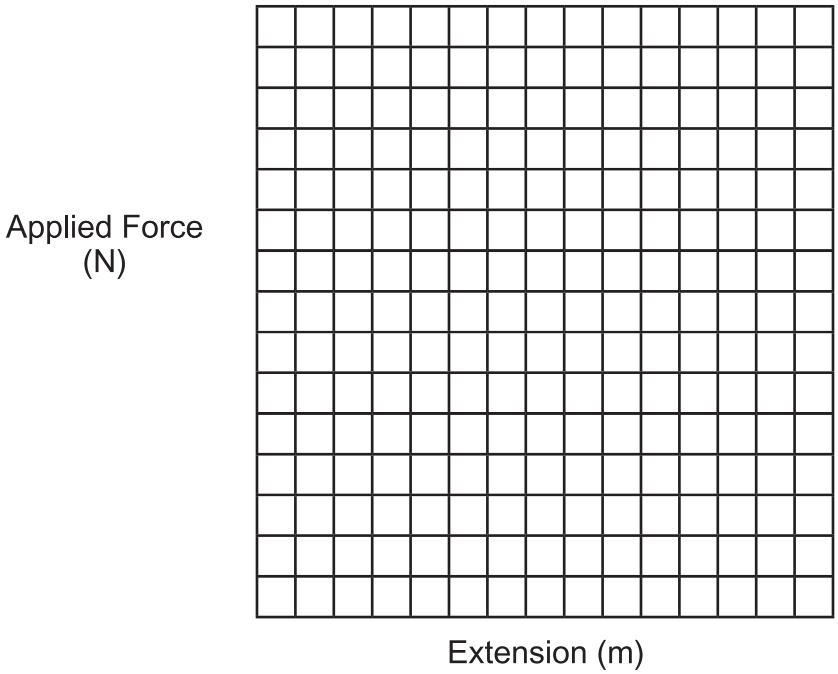
1. Hang a short spring and one of the long springs from the stand as in **Figure S2**.
2. Apply a series of five to ten different masses onto the short spring, starting with a 50-g mass. Note: Because the short spring stretches so easily, make sure that you do not hang so much weight on it that the spring is damaged.
3. Record the applied mass in kilograms, the applied force in Newtons (applied mass x 9.8 m/s²), and the extension in meters for each additional mass in **Data Table 2**.

Data Table 2

Short Spring Extension with Various Applied Forces

Trial	Applied Mass (kg)	Applied Force (N)	Extension (m)
1	0.050	0.49	*****

4. Plot a graph of applied force versus extension for the short spring. Notes: Add numbers to your grid lines to indicate the units you are using. Be sure to include the data point (0,0) because applying zero force obviously produces zero extension. Draw a best-fit line through the points you plotted.



5. Find the slope of the line in Newtons per meter (N/m) by dividing rise over run.

Slope for small spring: ____________________

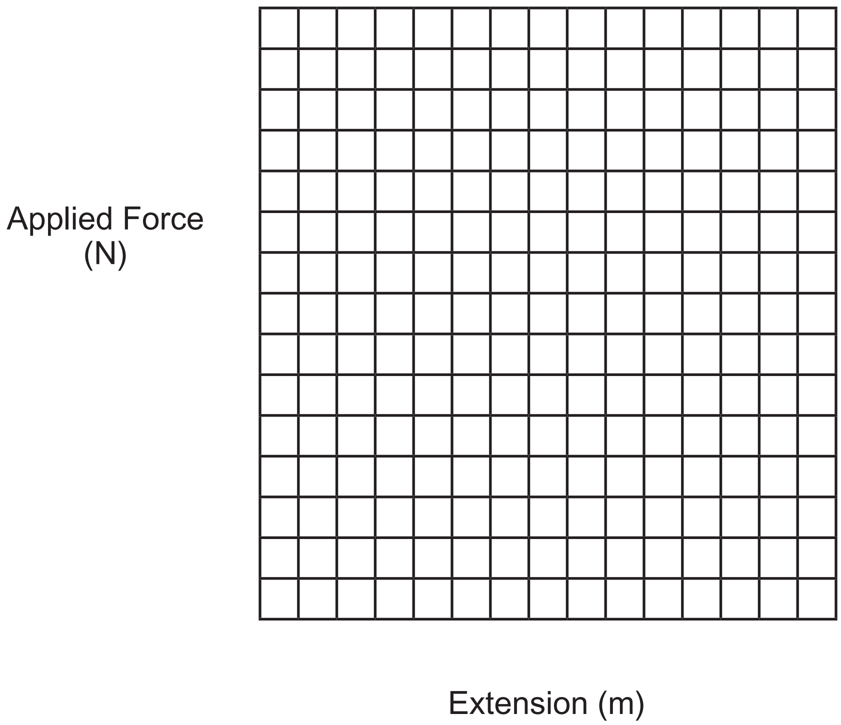
6. Note the color of the spring in **Data Table 3**.
7. Apply a series of five to ten different masses onto the long spring, starting with a 100-g mass.
8. Record the applied mass in kilograms, the applied force in Newtons (applied mass x 9.8 m/s²), and the extension in meters for each additional mass in **Data Table 3**.

Data Table 3

Long Spring Extension with Various Applied Forces (Color ___________)

Trial	Applied Mass (kg)	Applied Force (N)	Extension (m)

9. Plot a graph of applied force versus extension for the long spring. Notes: Add numbers to your grid lines to indicate the units you are using. Be sure to include the data point (0,0) because applying zero force obviously produces zero extension. Draw a best-fit line through the points you plotted.



10. Find the slope of the line in Newtons per meter (N/m) by dividing rise over run.

Slope for large spring: ____________________

Questions:

1. How would you describe the relationship of the data points for each of the springs?

2. In what way are the two springs similar? In what way are the two springs different?

3. Compare the values of the slopes with the values of the spring constants you found earlier.

4. Which value of the spring constant (one found from single measurements or one found from the slope) do you think more accurately describes the overall behavior of a spring? Explain your answer.

5. If you apply a Newton of force to a spring that is not stretched very much, does it produce a different stretch than an extra Newton of force added when it is more stretched? Explain how the graph supports and confirms this idea.

6. Draw a picture and describe how these springs could be made into spring scales. Which spring would be used for measuring the largest forces?

7. How would you change the spring scale you described to measure mass?

Extension Activities:

1. Repeat the experiment using various rubber bands. Compare the graph produced by a rubber band with the graphs produced by a coil spring. In what way(s) are the graphs similar? In what way(s) are the graphs different?

2. Use a spring or rubber band that has already been overextended. This means that the spring or rubber band will no longer go back to its original shape. Plot a graph of the applied force vs. the elongation. Compare this graph with the graphs produced by the other springs and rubber bands. In what ways are they similar and in what ways are they different?

Background:

You have already seen springs in series in Activity 3, but no attempt was made to relate the behavior to the spring constant. As you will recall, the spring constant is a number that numerically describes the behavior of a spring. In this respect, this activity will be similar to Activity 2, except that the springs will change in length rather than wire thickness.

At the end of this activity, you will be challenged to make predictions about the behavior of the magenta springs that you investigated earlier. If you can make these predictions, you can make predictions about the behavior of other springy objects with known spring constants.

There are many situations in our world that require similar predictions. The popping mechanism on a toaster is spring loaded and, while we want the mechanism to lift a variety of toast masses, it is not desirable to have the toaster shoot the toast up to the ceiling. This is best designed prior to building the toaster rather than using trial and error. Bungee jumpers use very long bungee cords to jump off of structures such as bridges. It is important to choose both the thickness and length of the cord so that the "ride" is both exciting and safe. Choosing a cord that is too long for the weight of the person jumping can result in disaster!

Objective:

- To investigate springs in series.
- To determine the spring constant of springs in series and how it relates to the spring constants of the individual springs.

Materials Needed:

Foundations of Physics Universal Stand
3 short springs (15 cm)
Metric ruler or meter stick
Mass hanger
Various masses (40 g, 80 g, 50 g, 100 g, 200 g, 500 g, 1 kg)
S-hooks from Activity 3

Procedure:

1. Use the S-hooks to connect the springs as shown in **Figure S10** (first one spring, then two in a series, then three in a series).
2. Apply a series of five to ten different masses on each short spring starting with a 50-g mass.
3. Record the applied mass in kilograms, the applied force in Newtons (applied mass x 9.8 m/s²), and the extension in meters for each additional mass in **Data Table 4** for one spring in a series.
4. Record the applied mass in kilograms, the applied force in Newtons (applied mass x 9.8 m/s²), and the extension in meters for each additional mass in **Data Table 5** for two springs in a series.
5. Record the applied mass in kilograms, the applied force in Newtons (applied mass x 9.8 m/s²), and the extension in meters for each additional mass in **Data Table 6** for three springs in a series.

Note: You may have already investigated the behavior of the single 15-cm spring in Activity 2. If so, you can copy the data from **Data Table 2** for this part into **Data Table 4**, then add masses to increase the force and complete the table.

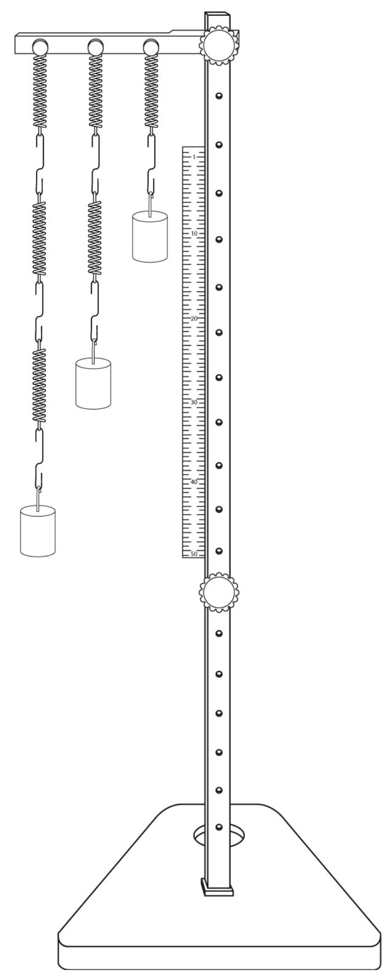


Figure S10

Data Table 4: One Spring in Series

Trial	Applied Mass (kg)	Applied Force (N)	Extension (m)

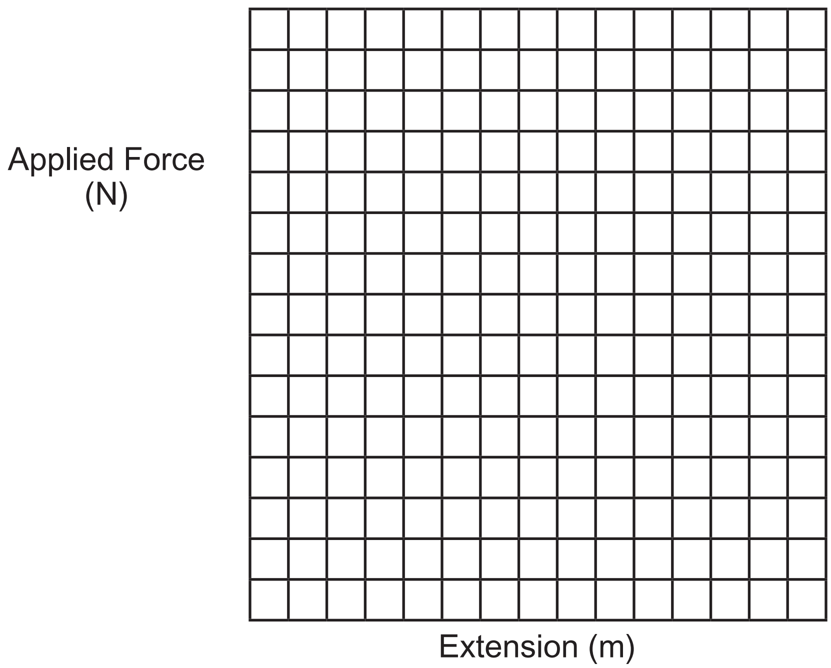
Data Table 5: Two Springs in Series

Trial	Applied Mass (kg)	Applied Force (N)	Extension (m)

Data Table 6: Three Springs in Series

Trial	Applied Mass (kg)	Applied Force (N)	Extension (m)

6. Plot a graph of applied force versus extension for each spring series on the graph below. Notes: Add numbers to your grid lines to indicate the units you are using. Be sure to include the data point (0,0) because applying zero force obviously produces zero extension. Draw a best-fit line through the points you plotted for each spring series.



7. Find the slope of the line in Newtons per meter (N/m) by dividing rise over run for each spring series.

Slope for one spring in series: ____________________

Slope for two springs in series: ____________________

Slope for three springs in series: ____________________

Questions:

1. In what way are the three springs similar? In what way are the three springs different?

2. How would you describe the relationship of the data points for each of these springs?

3. Compare the values of the slopes to each other. These slopes are definitely related to each other in a simple way. What is this relationship and why does it make sense?

Extension Activity:

Look up the spring constant that you measured for the magenta spring and use it to predict the spring constant for two of these springs hooked in series. Predict the amount of stretch that you expect from such a spring when a weight of 6 N is hung from the end. Try it and see if you are correct.

ACTIVITY 5: SPRINGS IN PARALLEL

Background:

In Activity 4, you found that the spring constant for springs in series is related to the spring constant of the individual springs. It would seem reasonable to assume that this is also true for springs in parallel. As you will recall, the spring constant is a number that numerically describes the behavior of a spring. In this respect, this activity will be similar to Activity 2: Stretching a Spring. Here, the springs will be changed by putting them side by side (in parallel). This is somewhat like changing the thickness of the spring's wire.

There are many situations that use springs in parallel. Motorcycles and cars both have two springs in the front and rear that are in parallel. In both motorcycles and cars, the loads applied to them make them compress rather than extend, but springs behave in the same way in compression as in extension. It is important for engineers to be able to predict how parallel springs will compress so that a vehicle's ride will be comfortable.

Objective:
- To investigate springs in parallel.
- To determine the spring constant of springs in parallel and how it relates to the spring constants of the indiviual springs.

Materials Needed:
Foundations of Physics Universal Stand
3 short springs (15 cm)
Triangle connector
Clear plastic reading bar
Metric ruler or meter stick
Mass hanger
Various masses (50 g, 100 g, 200 g, 300 g, 400 g, 500 g, 1 kg)

Procedure:
1. Set up the two short springs in parallel as shown in **Figure S11**.
2. Connect the bottoms of the springs with the triangular connector.
3. Apply a series of five to ten different masses on each short spring, starting with a 50-g mass.
4. Record the applied mass, the applied force and extension for each additional mass in **Data Table 7** for one spring.
5. Record the applied mass, the applied force and extension for each additional mass in **Data Table 8** for two springs in parallel.
6. Record the applied mass, the applied force and extension for each additional mass in **Data Table 9** for three springs in parallel.

Note: You may have already investigated the behavior of the single 15-cm spring in Activity 2. If so, you can copy the data from **Data Table 2** for this part into **Data Table 7** and start out with two springs side by side (i.e. parallel).

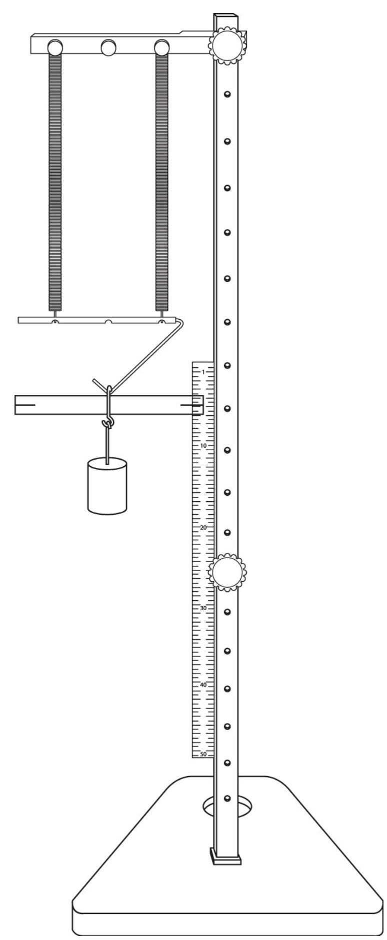


Figure S11

Data Table 7: One Spring

Trial	Applied Mass (kg)	Applied Force (N)	Extension (m)

Data Table 8: Two Springs in Parallel

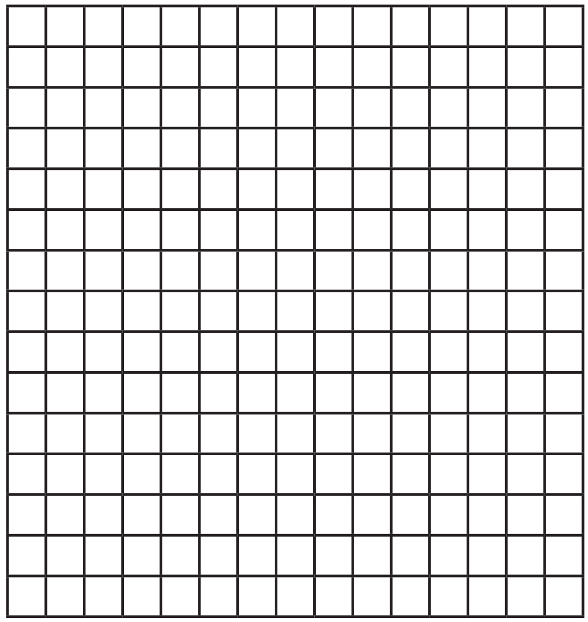
Trial	Applied Mass (kg)	Applied Force (N)	Extension (m)

Data Table 9: Three Springs in Parallel

Trial	Applied Mass (kg)	Applied Force (N)	Extension (m)

7. Plot a graph of applied force versus extension for each parallel spring situation on the graph below. Notes: Add numbers to your grid lines to indicate the units you are using. Be sure to include the data point (0,0) because applying zero force obviously produces zero extension. Draw a best-fit line through the points you plotted for each spring situation.

Applied Force (N)



Extension (m)

Questions:

1. When additional springs are placed in parallel, is the combination easier or harder to stretch than with fewer springs? Explain why you think this makes sense.

2. If one spring is harder to stretch than another, does it have a larger or smaller spring constant?

3. How would you describe the relationship of the data points for each of these springs?

4. Compare the values of the slopes to each other. These slopes are definitely related to each other in a simple way. What is this relationship and why does it make sense?

Extension Activity:

Look up the spring constant that you measured for the magenta spring and use it to predict the spring constant for two or three of these springs hooked in parallel. Predict the amount of stretch that you expect from such a spring when a weight is hung from the end. Try it and see if you are correct.

Background:
You may have noticed that if you give one of your spring systems a bit of a vertical shove, it vibrates up and down in a very regular way. The spring is oscillating. The period of oscillation (T) is the amount of time required for a specific spring to make one complete back-and-forth oscillation. Take a few minutes and try it out.

Objective:
- Predict the period of oscillation.
- Test your predictions using a simulation.

Materials Needed:
Foundations of Physics Universal Stand
3 long springs (1 magenta, 1 green, 1 blue)
3 short springs (15 cm)
Triangle connector
Clear plastic reading bar
Metric ruler or meter stick
Mass hanger
Various masses (50 g, 100 g, 200 g, 300 g, 400 g, 500 g, 1 kg)

Procedure:
1. Mount the three long springs (green, magenta, blue) in the spring connector.
2. Put a mass of 1,000 grams on each of the springs, give it a small vertical shove, and watch it oscillate.
3. Time 10 complete oscillations of each spring and find the period for one oscillation by dividing the time it takes for 10 oscillations by 10.
4. Look up your value of the spring constant for each of these springs and include this in **Data Table 10.**

Data Table 10: Period of Oscillation

Spring (color)	Spring Constant (k) (N/m)	Time for 10 Vibrations (s)	Period (T) (s)
Green			
Magenta			
Blue			
Short			

5. Mount one of the short springs in the spring connector.
6. Put a mass of 5 grams on the spring. Notice that the mass oscillates more slowly than the other situations.
7. Find the period of oscillation as you did in step 3 and record it in **Data Table 10.**

Questions:
1. How does the period of vibration differ for the three long springs?

2. What things are the same for these three springs?

Extension Activity:
More important than the value of the period is that you can now notice how the oscillations are regular in their motion. In spite of this, it is still impossible to describe this motion in detail merely by observing it. We could graph this motion by attaching a felt pen, to the bottom of the oscillating mass allowing the tip to gently touch a cardboard screen, as in **Figure S12**.

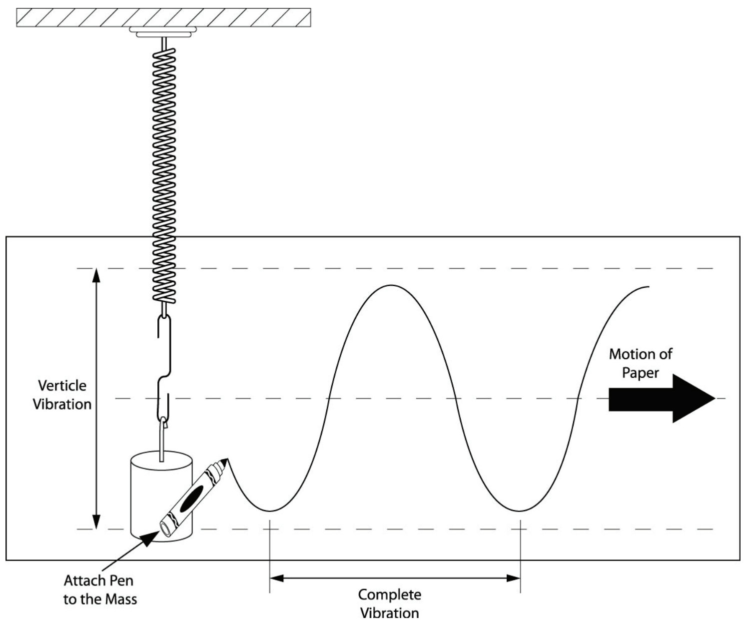


Figure S12

Simulation:
The vertical vibration will create a vertical line marked on the screen. If the screen is moved horizontally at a steady rate, the pen will trace out its changing vertical position at different times, as in the figure above. It will also be seen that the motion is repetitious and produces a regular mathematical curve.

PHILIP
HARRIS

0345 120 4521

techsupport@philipharris.co.uk

www.philipharris.co.uk

Philip Harris Education
2 Gregory Street, Hyde, Cheshire SK14 4TH