Spring Rate Activity

STEM Lesson for TI-Nspire™ Technology

Objective: Students will investigate rate of change (slope) using spring data from RC cars.

About the Lesson: In NASCAR, the selection of springs (and spring rate) determines the ride height of the car. If a NASCAR racer has 500 lbs down force on the front of the car and 250 lbs/in springs in the car, the front of the car will go down 1.00" (two springs, each carrying half the load) when it is at speed and the aero load is fully developed. Different springs take more or less weight to compress depending on the spring rate; therefore, crew chiefs can predict which spring to use for different chassis setups.

<u>Teacher Tip:</u> *This procedure is very time consuming, so sample data is provided below for shorter class periods. This investigation would be a wonderful activity for peer teaching. For example, the experiment is done in science class and the analysis is done in the math class using the data from the experiment.*

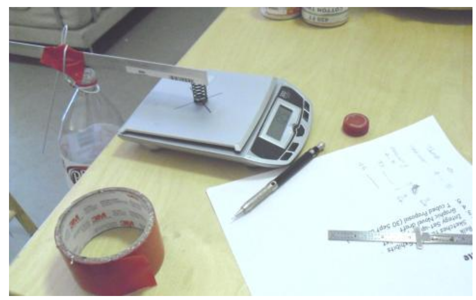
Spring 1		*Spring 2*		*Spring 3*	
lbs.	*in.*	*lbs.*	*in.*	*lbs.*	*in.*
0	*0*	*0*	*0*	*0*	*0*
0.160938	*0.03125*	*0.517*	*0.030*	*0.451047*	*0.0303*
1.124358	*0.109375*	*1.470*	*0.080*	*1.48724*	*0.1073*
1.96432	*0.203125*	*3.190*	*0.170*	*2.1722*	*0.1582*

Materials: 3 different size RC springs
Digital Scale
Machinist’s scale or a tool to measure small distances
Metal bar or similar stiff light weight beam
Chair
String
2L drink bottle
Water
Student Worksheets

Prerequisite skills: The students need to be familiar with scatter plots.

Procedure:

1. Set a digital scale on a table or low countertop. If your length measuring device is in inches, set the units to ounces (oz) or pounds (lbs.). If you measure length in millimeters, set the scale to grams (g).
2. Place one of the springs in the middle of the digital scale.
3. Place one end of a metal bar or similar stiff light weight beam (meter stick) on the spring and the other end on a chair or another table that is the same height as the object in step 1.
4. Tie one end of a piece of string around the neck of a 2L drink bottle and the other end to the beam close to the spring. The bottle should be at lease 0.5" away from the table or countertop.

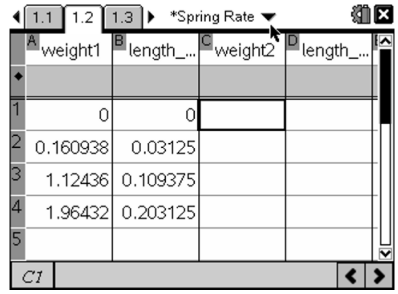


5. Measure the length of the spring as exact as possible. Record the length.
6. Pour water into the bottle until the spring starts to compress. Measure and record the new length of the spring and the weight from the scale.
7. Pour more water into the bottle until the spring is a little over half compressed. Measure and record the new length and the weight from the scale.
8. Pour more water into the bottle until the spring is completely compressed. Measure and record the compressed length and the weight from the scale.
9. Calculate how much the spring length changed between each measurement.
10. Repeat steps 5-8 for 2 more different size springs.

Analysis:

On your handheld, go to My Documents and open the file named *Spring Rate.tns*.

1. Move to page **1.2**. Enter the weight and **change** in length data for spring 1 in the first two columns, spring 2 for the next two columns, and spring 3 in the next two. Start with a weight of 0 and a 0 change in length.



	A weight1	B length_...	C weight2	D length_...
1	0	0		
2	0.160938	0.03125		
3	1.12436	0.109375		
4	1.96432	0.203125		
5				

2. Now we need to create a scatter plot for each set of data for weight vs. change in length. Move to page **1.3**.

3. Which variable is the independent variable x?

   Answer: Change in length

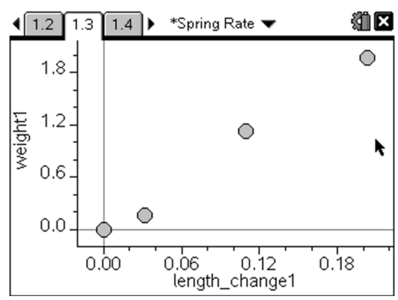
4. Which variable is the dependent variable y?

   Answer: Weight

Navigator Tip: *Quick Poll the students for their answers to #3 and #4 and show the results to start a good discussion and to make sure the students know which variable goes on which axis.*

5. Move the cursor to the bottom of the screen where it says "click to add variable". Press x and choose **length_change1**.

6. Move the cursor to the middle of the left side of the screen until a rectangle appears. Press x and choose **weight1**.



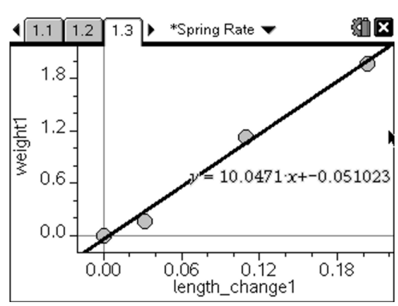
The rate at which something is changing is comparing how fast or how slow one unit is changing compared to another unit. For example if snow is falling at a rate of 0.25 in. per hr., then it means every hour their will be another 0.25 in on the ground in addition to what is already there. After 4 hours their will be 1.00 in on the ground. Once the data is on a graph, we can easily calculate the rate of change of collected data using the formula $(y_2-y_1)/(x_2-x_1)$ where the variables are the coordinates of the data points.

7. For the data for spring 1, at what rate is the length changing compared to the weight? Use the first collected data point instead of (0,0) for better results.

   Answer: For the provided data,
   (1.96432-0.160938)/(0.203125-0.03125) = 10.4924 lbs/in

   Experimental data for each student will cause answers to vary.

8. Press b **>> Analyze >> Regression >> Show Linear(mx+b)**

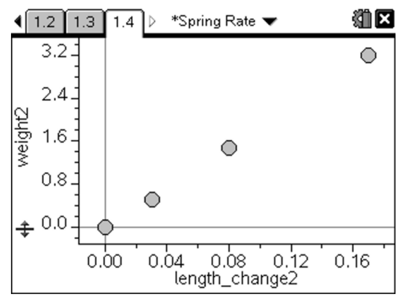


9. Which number in the equation on the screen is closest to your answer in **Question 7**?

   Answer: The first number or the number before the *x*. This is true for the provided data or any student experimental data.

> **<u>Navigator Tip:</u>** *Quick Poll the students for their answers and show the results to start a good discussion and make sure the students have the correct answer. If the students are all using different data but get the same answer to #9, it will reinforce the fact that slope is always the coefficient of x.*

10. Now we need to create a scatter plot for the other 2 springs. Move to page **1.4**.



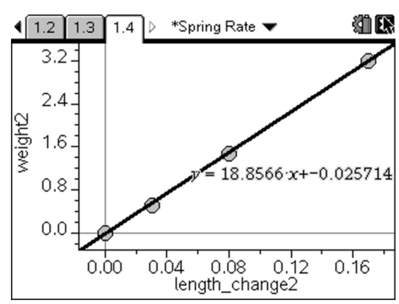
11. Move the cursor to the bottom of the screen where it says "click to add variable". Press x and choose **length_change2**.

12. Move the cursor to the middle of the left side of the screen until a rectangle appears. Press x and choose **weight2**.

13. Using the data for spring 2, find the rate at which the length changes compared to weight.

    Answer: For the provided data,
    (3.19-0.517)/(0.17-0.03) = 19.0929 lbs/in

    Experimental data for each student will cause answers to vary.



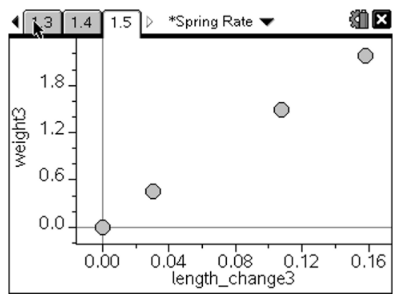
14. Press b **>> Analyze >> Regression >> Show Linear(mx+b)**

15. Which number in the equation on the screen is closest to your answer in **Question 13**?

Answer: The first number or the number before the *x*. This is true for the provided data or any student experimental data.

Navigator Tip: *Quick Poll the students for their answers and show the results to start a good discussion and make sure the students have the correct answer. If the students are all using different data but get the same answer to #15, it will reinforce the fact that slope is always the coefficient of x.*

16. Move to page **1.5**. Create a scatter plot for the data for spring 3.

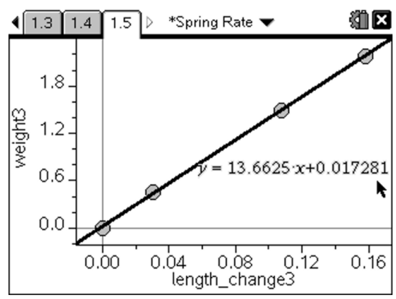


17. Using the data for spring 3, find the rate at which the length changes compared to weight.

Answer: For the provided data,
(2.1722-0.451047)/(0.1582-0.0303) = 13.4547 lbs/in

Experimental data for each student will cause answers to vary.

18. Press b **>> Analyze >> Regression >> Show Linear(mx+b)**



19. Which number in the equation on the screen is closest to your answer in **Question 17**?

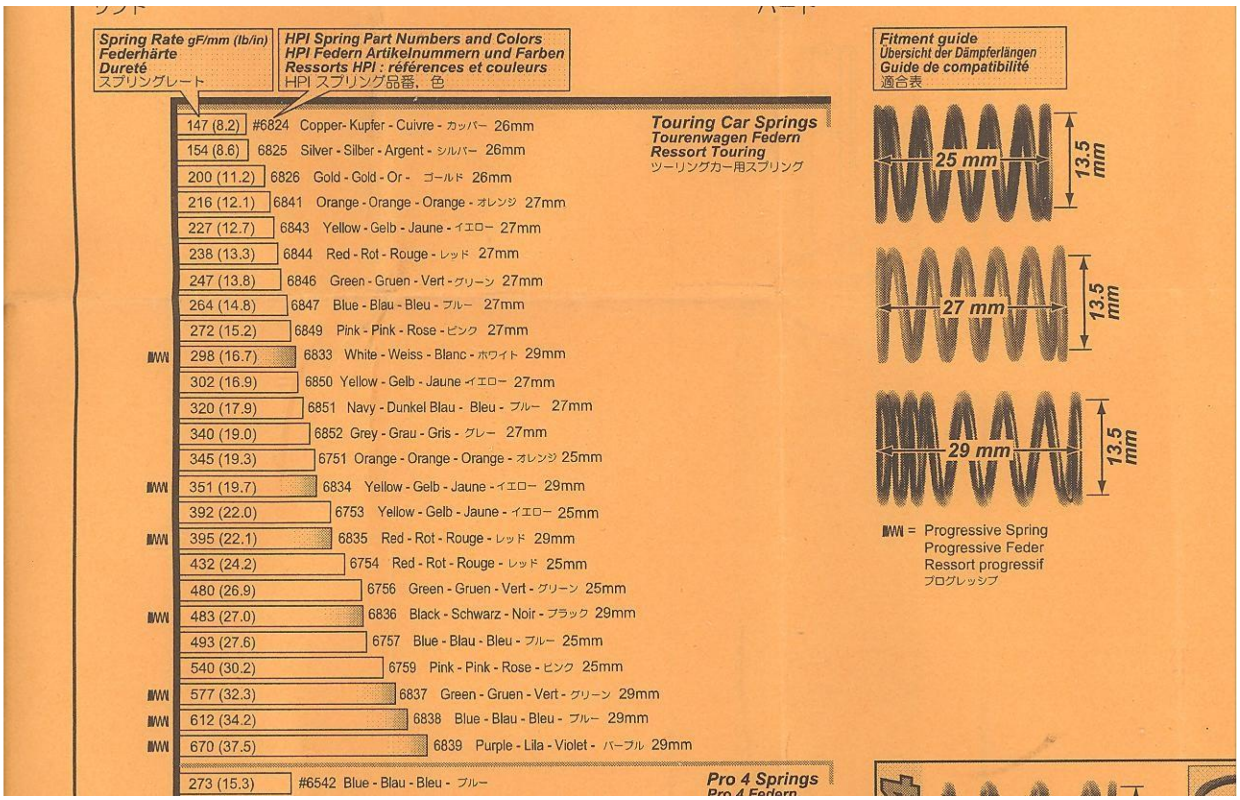
Answer: The first number or the number before the *x*. This is true for the provided data or any student experimental data.

Navigator Tip: *Quick Poll the students for their answers and show the results to start a good discussion and make sure the students have the correct answer. If the students are all using different data but get the same answer to #15, it will reinforce the fact that slope is always the coefficient of x.*

20. Make a conjecture about writing an equation given the rate of change.

    Answer: The rate of change will always be the coefficient of *x*.

When we model data with a graph, the rate of change is called the **slope** of the line through the data points. The equation of that line is another way to model data. These models allow us to calculate other data points and make predictions. Spring manufacturers use the slope to rate the spring. Below is an example of a manufacturers spring chart.



Spring Rate gF/mm (lb/in) Federhärte Dureté スプリングレート	HPI Spring Part Numbers and Colors HPI Federn Artikelnummern und Farben Ressorts HPI : références et couleurs HPI スプリング品番，色
147 (8.2)	#6824 Copper- Kupfer - Cuivre - カッパー 26mm
154 (8.6)	6825 Silver - Silber - Argent - シルバー 26mm
200 (11.2)	6826 Gold - Gold - Or - ゴールド 26mm
216 (12.1)	6841 Orange - Orange - Orange - オレンジ 27mm
227 (12.7)	6843 Yellow - Gelb - Jaune - イエロー 27mm
238 (13.3)	6844 Red - Rot - Rouge - レッド 27mm
247 (13.8)	6846 Green - Gruen - Vert - グリーン 27mm
264 (14.8)	6847 Blue - Blau - Bleu - ブルー 27mm
272 (15.2)	6849 Pink - Pink - Rose - ピンク 27mm
298 (16.7)	6833 White - Weiss - Blanc - ホワイト 29mm
302 (16.9)	6850 Yellow - Gelb - Jaune イエロー 27mm
320 (17.9)	6851 Navy - Dunkel Blau - Bleu - ブルー 27mm
340 (19.0)	6852 Grey - Grau - Gris - グレー 27mm
345 (19.3)	6751 Orange - Orange - Orange - オレンジ 25mm
351 (19.7)	6834 Yellow - Gelb - Jaune - イエロー 29mm
392 (22.0)	6753 Yellow - Gelb - Jaune - イエロー 25mm
395 (22.1)	6835 Red - Rot - Rouge - レッド 29mm
432 (24.2)	6754 Red - Rot - Rouge - レッド 25mm
480 (26.9)	6756 Green - Gruen - Vert - グリーン 25mm
483 (27.0)	6836 Black - Schwarz - Noir - ブラック 29mm
493 (27.6)	6757 Blue - Blau - Bleu - ブルー 25mm
540 (30.2)	6759 Pink - Pink - Rose - ピンク 25mm
577 (32.3)	6837 Green - Gruen - Vert - グリーン 29mm
612 (34.2)	6838 Blue - Blau - Bleu - ブルー 29mm
670 (37.5)	6839 Purple - Lila - Violet - パープル 29mm
273 (15.3)	#6542 Blue - Blau - Bleu - ブルー

The first column is the rate for each spring. The first number is in grams per millimeter and the number in parentheses is in pounds per inch.

21. Round your answer from **Question 7** to the tenths place. Which spring from the chart has the closest rating to your rating?

    Answer: For the provided data, 10.5 lbs/in which is closest to the #6826 Gold spring. Some students may answer that it isn't on the list, or this company doesn't have this size, or it is in between the Silver and Gold. All of these answers should be accepted.

22. Round you answer from **Question 13** to the tenths place. Which spring from the chart has the closest rating to your rating?

    Answer: For the provided data, 19.1 lbs/in which is closest to the #6852 Grey spring or the #6751 Orange spring.

23. Round you answer from **Question 17** to the tenths place. Which spring from the chart has the closest rating to your rating?

    Answer: For the provided data, 13.5 lbs/in which is closest to the #6844 Red spring or the #6846 Green spring.

24. Which spring is the stiffest?

    Answer: For the provided data, spring 2. It is the spring with the most lbs/in rate of change.

25. Which line was the steepest?

    Answer: For the provided data, spring 2.

26. How does the slope of the line compare to the spring stiffness?

    Answer: As the slope increases, the spring stiffness increases.

27. If you were the crew chief, which spring would you recommend in this situation? Your car's weight will never change more than 13 lbs., and you don't want the body to move more than 1 in.

    Answer: The rate of change would be 13 lbs/in or less so the best spring would be the #6843 Yellow spring

EXTENSION

28. Write an equation modeling the compression of a spring with the rating of 34.2 lbs/in.

    Answer: y = 34.2x

29. Use your equation to predict how much weight it will take to compress the spring 0.75 in.

    Answer: 25.65 lbs

30. Use your equation to predict how far the spring will compress with a weight of 15 lbs.

    Answer: 0.438596 in