Science
Physical Science
Grade 4
Pendulum Activity

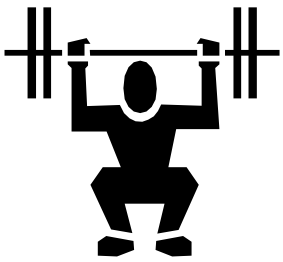
<u>Overview</u> (for the teacher)

A pendulum is a suspended mass that has the ability to swing freely. Students will be familiar with this concept by their experience with a playground swing. A pendulum swings because it is falling due to the pull of gravity. The string prevents the mass from falling straight down to the ground. The mass reaches its lowest point and keeps moving due to its momentum. The mass swings to a maximum height, then begins to fall again. The pendulum swings back and forth until it eventually loses energy and comes to a stop.

A change in the pendulum mass does not change the rate of the pendulum swing as many students commonly think. No matter the how heavy, all objects fall at the same rate of acceleration, 9.8 m/s^2. A common analogy to this occurs when two vehicles stop at light at a traffic light and accelerate at the same rate to the next corner. No matter what the difference in size, weight, or volume, the vehicles will reach the corner at the same time because they are speeding up at the same rate. The force of gravity is **measured** by how quickly it makes an object speed up.

A decrease in the string length that suspends a mass will increase the swing rate of the pendulum. A short string makes a tighter turning radius for the same rate of acceleration. Students have observed the increase in swing rate when the chains on a playground swing are shortened.

The issue of **weight** versus **mass** can be confusing. The mass of an object is always constant, assuming that the amount of matter is constant. The weight of an object can vary even on Earth because it is the measure of the amount of matter and the acceleration due to gravity. Gravity varies slightly on the surface of Earth. The closer an object is to the center of Earth, the greater the acceleration, due to gravity. So as mass remains constant, gravity can vary; therefore, weight can vary.



Resources

How Pendulums Work
http://www.physics.northwestern.edu/classes/2001Spring/135-1/Projects/5/page3.html

Amusement Park Physics
http://www.learner.org/exhibits/parkphysics/pendulum.html

Benchmarks

SI-E-A2 Planning and/or designing and conducting a scientific investigation

SI-E-A3 Communicating that observations are made with one's senses

SI-E-A4 Employing equipment and tools to gather and extend the sensory observations

SI-E-A7 Utilizing safety procedures during experiments

PS-E-B3 Describing an object's motion by tracing and measuring its position over time

PS-E-B4 Investigating and describing how the motion of an object is related to the strength of the force (pushing or pulling) and the mass of the object

Teacher Preparation

1. Cut the string into lengths about 1 meter. Make sure the string is cotton. Synthetic string tends to become untied.

2. Tie a large paper clip to each end of the string.

3. Assemble all the materials in a central location.

Open

Class Discussion- 15 minutes

- Group students in pairs.
- Issue the handout, *Swing Time*.
- Ask a student to read the problem in the box at the beginning of the activity aloud.
- Ask students the following questions:

1. What is being tested?
   [the factors that affect the rate of a pendulum swing]

2. Do you think a heavier weight will cause the pendulum to swing faster?
   [Students may think that a heavier mass will make the pendulum swing faster. Accept all answers without comment. Do not provide the correct answer to students at this time. Allow them to discover which factor affect the rate of swing.]

3. Do you think changing the length of the string will cause the pendulum to swing faster? Will it swing faster with a short string or a long string?
   [*Students may not know that a shorter string with cause a faster swing- go on to the next question. Do not provide the correct answer to students at this time. Allow them to discover which factor affects the rate of swing.]*

4. How is a playground swing like a pendulum?
   [it swings]

5. What happens on the playground when you shorten the length of the chains?
   [Students may not know the answer to this question. You can tell students that they can use the pendulum as a model for a swing to answer this question. Accept all answers without comment. Explain that they will discover the answer as they carry out this investigation.]

6. Would a larger person swing slower that a smaller person if the swing is pulled back and released, not pushed?
   [Students may not know the answer to this question. You can tell students that they can use the pendulum as a model for a swing to answer this question.]

7. How can we find out if you are correct about the swing rate? How could you use a string and some washers to test your guess for different weights? For different string length?

   Teacher direction- hold up a string with washers tied on one end. You may need to lead students in designing the experiment. Write the directions students provide on the board.
   [answers will vary- change the length of the string and count the swings, and change the number of washers and count the swings]

8. Will a difference in weight or string length affect the swing rate? Your answer is your hypothesis.

   Teacher Direction: Agree on one hypothesis for weight and one for string length. Write the hypotheses on the board where it will not get erased. Students will refer to the statements during the *Data Analysis*.

The ***difference in pendulum weight*** (Tested Variable) will cause ***a difference in swing rate*** (Outcome).

9. How can we measure how fast the pendulum swings?
   [count the number of swings per unit time]

10. Why is it important that results are measured and not just described by words?
    [numbers are less ambiguous compared to other forms of description]

Body of the Lesson

To the teacher: Students should be assembled in groups of two. Distribute the activity handout, *Swing Time.* Introduce the activity with the following discussion.

1. What are you going to do in this lab activity first (second, third etc.)? Look at the handout to answer.
   [Let students call out the step-by-step procedure written in the activity.]

2. Why is it important to follow the teacher's directions during a lab activity?
   [It is always important to follow teacher directions so accidents will be less likely.]

3. Before you begin the experiment, you must read the directions thoroughly.

4. One student per group may gather the materials and equipment needed for the activity. No other students may be out of their seats during the activity.

5. When the activity is completed one student per group will return the equipment to the teacher.

6. Failure to properly clean a work area will result in 10 points being deducted from the grade of each member of the offending group.

Activity- 25 Minutes **(Student Sheets** beginning on page 98**)**

Read each activity question to the class. Call on each student group of 2 in turn for the answers. Students may write the answers to the questions on their handouts.

Data Analysis- 25 Minutes (Student Record Sheet begins on p.100)

1. What were you testing in this activity?
   [factors that affect the swing rate of a pendulum]

2. What happened in the test?
   [The change in string length affected the swing rate, and the change in weight did not affect the swing rate]

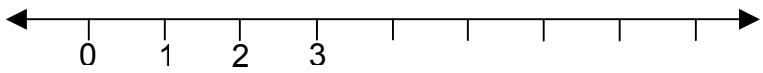
3. In order to compare groups of data, average the trials for different weights and string lengths. Record the averages in the tables.

   Teacher Direction: Ask students the following-

   a) How do you take the average of 3 numbers like: 1, 2 and 3?

   Teacher Direction: If students cannot answer the question, continue. If students answer correctly skip to **(d)**.

   Teacher Direction: Draw a number line on the board. Plot 1, 2 and 3 on the line.



   b) What is the midpoint between 1, 2 and 3?
      [2]

   c) That number is also the average. How can you calculate an average without plotting numbers on a number line?
      [Add the numbers 1, 2, 3 and divide by the count of numbers, 3.]

   d) How are you going to find the average of the swings for 1 washer at the short string length?

$$\left(\frac{(\text{Trial 1} + \text{Trial 2} + \text{Trial 3})}{3} \right)$$

4. Find the change in swing rate for different weights and then for different string lengths. Record the differences in the tables.

5. Can you prove that the change in string length had an effect on swing rate and the change in mass did not with the data you collected?
   [The data from the experiment showed_____]

6. A test of a “guess” is called an experiment. An experiment should include a control group and an experimental group. The experimental group is the test of your guess. Describe your experimental group.
[For one hypothesis it is a change in string length.For the other hypothesis it is a change in mass]

7. The control group is used to compare to the outcome of the test so you are sure what is responsible for the outcome of the test. Describe your control group. *[The original weight and string length swing rate is used to compare the changed original weight and string length swing rate]*

8. Write the hypothesis for the experiment. Fill in the blanks below.

The ***change in pendulum weight*** (Tested Variable) will ***change the swing rate*** (Outcome).

**** Students may say that swing rate will increase or decrease with an increase in weight.***

The ***change in swing length*** (Tested Variable) will ***change the swing rate*** (Outcome).

**** Students may say that swing rate will decrease, increase or stay the same with an increase in string length.***

Teacher Direction: Refer students to the hypothesis they gave you on the first day of the lab activity. It should be on the board.

SAMPLE DATA

Table 1: Change in Weight

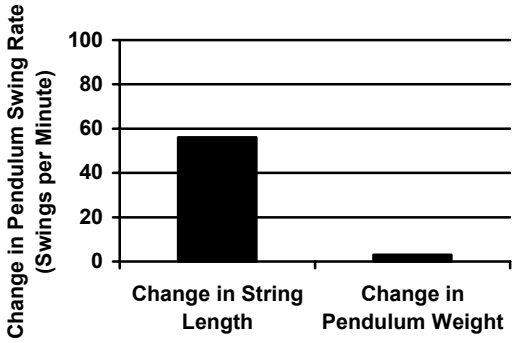
Trial Number	String Length (cm)	Number of Washers	Number of Swings in 30 Seconds	Number of Swings in 60 Seconds	Number of Swings in 1 Minute
1	***30***	***1***	***28***	***56***	***56***
2	***30***	***1***	***29***	***58***	***58***
3	***30***	***1***	***30***	***60***	***58***
Average Number of Swings in 1 Minute for 1 Washer					***56***
4	***30***	***4***	***30***	***60***	***60***
5	***30***	***4***	***31***	***62***	***62***
3	***30***	***4***	***28***	***56***	***56***
Average Number of Swings in 1 Minute for 4 Washers					***59***
Change in Swing Rate					***3***

Table 2: Change in Length

Trial Number	String Length (cm)	Number of Washers	Number of Swings in 30 Seconds	Number of Swings in 60 Seconds	Number of Swings in 1 Minute
1	***30***	***1***	***27***	***54***	***54***
2	***30***	***1***	***30***	***60***	***60***
3	***30***	***1***	***28***	***56***	***56***
Average Number of Swings in 1 Minute for a Short String					***57***
4	***50***	***1***	***20***	***40***	***40***
5	***50***	***1***	***19***	***38***	***38***
6	***50***	***1***	***18***	***36***	***36***
Average Number of Swings in 1 Minute for a Long String					***38***
Change in Swing Rate					***19***

9. A bar graph shows comparisons. Label the x-axis where you intend to draw a bar for the control and experimental groups. Hold up your papers and show your labels.

10. Use the data in the table to draw a bar to the correct height on the graph for the experimental group and the control group. Hold up your papers and show your graphs



11. According to the graph, is the hypothesis about differences in weight and the swing rate proven? What evidence supports your statement?
[The hypothesis that weight would change the swing rate was incorrect. The swing rate for 1 washer was an average of 56 swings per minute. The swing rate for 4 washers was an average of 59 swings per minute.]
**** Students may say that swing rate will increase, decrease or stay the same with an increase in weight.***

12. According to the graph, is the hypothesis about differences in string length and swing rate proven? What evidence supports your statement?
[The hypothesis that weight would change the swing rate was incorrect. The swing rate for a 50 cm string length was an average of 56 swings per minute. The swing rate for a 25 cm string length was an average of 112 swings per minute.]
**** Students may say that swing rate will increase, decrease or stay the same with an increase in string length.***

Close
Journal Entry-10 Minutes

Ask students to keep a science journal. Use student entries to plan future lessons. At the end of the class period ask students to enter their responses to the following prompts into their journals:

1. What did you learn today?
2. What questions would you like to ask about the lesson?
3. What would you like to know more about?

STUDENT SHEETS – *Swing Time* Activity

Materials per Student Group
100 Centimeter Length of String with a Large Paper Clip Tied to Both Ends
4 Large Washers
Centimeter Ruler
15 cm of Duct Tape
Clock or Watch With Second Hand or Stop Watch

Safety
Directions: Use common knowledge to answer the question.

- Why is it important to follow the teacher's directions during a lab activity?

Activity

1. Slip one large washer onto the paper clip at the end of the string.

2. Attach one end of the string to the desk with a piece of duct tape. Tape the string onto the desk so that the short end with the paper clip is not covered and the long end hangs down freely.

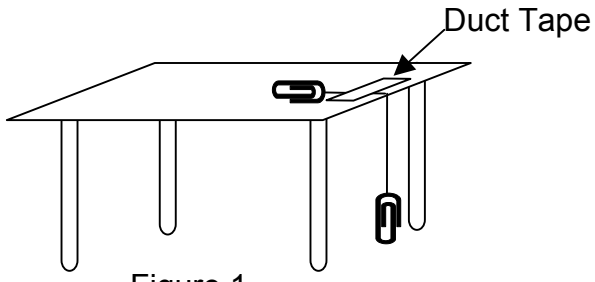


Figure 1

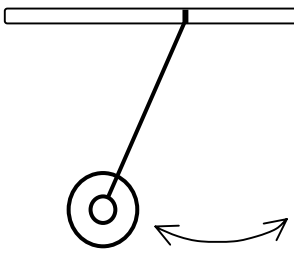
3. Measure the length of the string that is **hanging off the desk** and record the distance and the number of washers in Table 1.

4. Pull the washer back so that it is level with the desk.

5. One student will **release** the washer (do not push the washer); another student will count the number of swings that occur 30 seconds.
(See the figure 2.)

6. Record the number of swings in Table 1. Repeat two more times.

Figure 2



7. Add 3 washers to the string and count the number of swings in 30 seconds.

8. Record the number of swings and washers in the table. Repeat two more times.

9. Adjust the string length so that it is about half the original length. Measure and record the new length and the number of washers in the table.

10. Swing the pendulum from the new height and count the number of swings in 30 seconds.

11. Record the number of swings and washers in Table 2.

12. Repeat two more times.

Table 1: Change in Weight

Trial Number	String Length (cm)	Number of Washers	Number of Swings in 30 Seconds	Number of Swings in 60 Seconds	Number of Swings in 1 Minute
1					
2					
3					
Average Number of Swings in 1 Minute for 1 Washer					
4					
5					
3					
Average Number of Swings in 1 Minute for 4 Washers					
Change in Swing Rate					

Table 2: Change in Length

Trial Number	String Length (cm)	Number of Washers	Number of Swings in 30 Seconds	Number of Swings in 60 Seconds	Number of Swings in 1 Minute
1					
2					
3					
Average Number of Swings in 1 Minute for a Short String					
4					
5					
6					
Average Number of Swings in 1 Minute for a Long String					
Change in Swing Rate					

Data Analysis

1. What were you testing in this activity?

2. What happened in the test?

3. In order to compare groups of data, average the trials for different weights and string lengths. Record the averages in the tables.

4. Find the change in swing rate for different weights and then for different string lengths. Record the differences in the tables.

5. Can you prove that the change in string length had an effect on swing rate, and the change in mass did not, with the data you collected?

6. A test of a “guess” is called an experiment. An experiment should include a control group and an experimental group. The experimental group is the test of your guess. Describe your experimental group?

7. The control group is used to compare to the outcome of the test so you are sure what is responsible for the outcome of the test. Describe your control group.

8. Write the hypothesis for the experiment. Fill in the blanks below.

The _____ will cause
Tested Variable

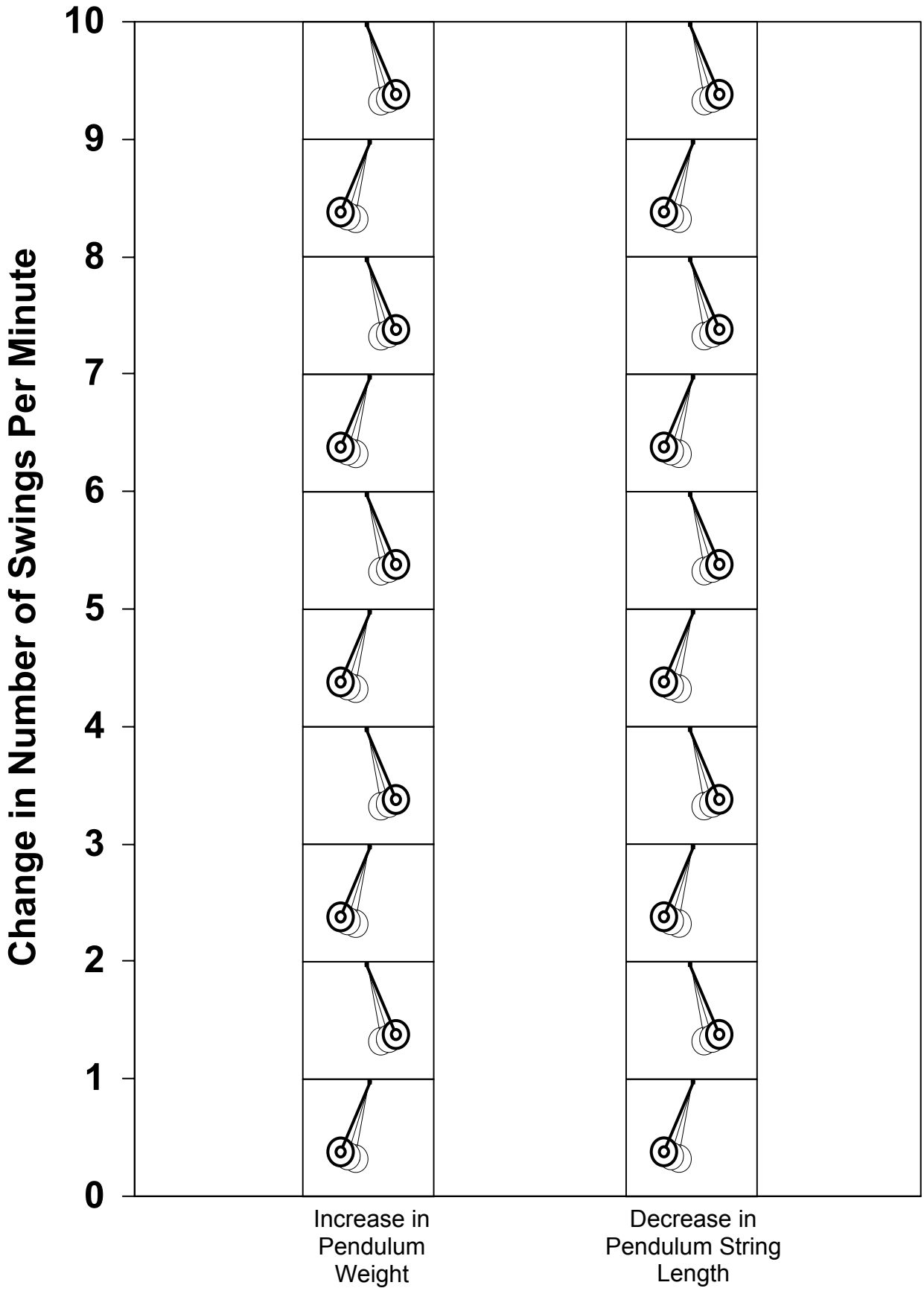
_____.
Outcome

9. A bar graph shows comparisons. Label the x-axis where you intend to draw a bar for the control and experimental groups. Hold up your papers and show your labels.

10. Use the data in the table to shade the pendulum pictures to to the correct height on the bar graph for the experimental group and the control group. Hold up your papers and show your graphs

11. According to the graph, is the hypothesis about differences in weight and swing rate proven? What evidence supports your statement?

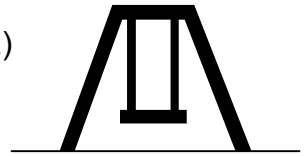
12. According to the graph, is the hypothesis about differences in string length and swing rate proven? What evidence supports your statement?

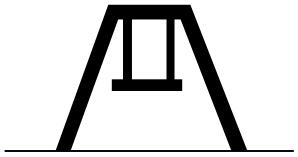

Change in Number of Swings Per Minute
10
9
8
7
6
5
4
3
2
1
0
Increase in Pendulum Weight
Decrease in Pendulum String Length

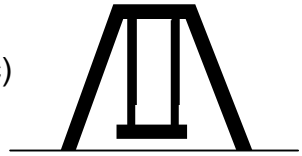
Swing Time Assessment

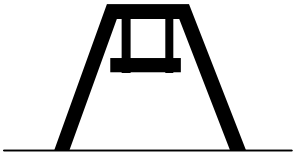
Directions: Use the graph to answer each question below.

1. Given the same push, which swing will swing the fastest?

a) 

b) 

c) 

d) 

2. In the pendulum experiment you proved that weight does not affect how fast a pendulum swings. Using this information, what would happen if a paper clip and a large washer fall from a table at the same height and at the same time?

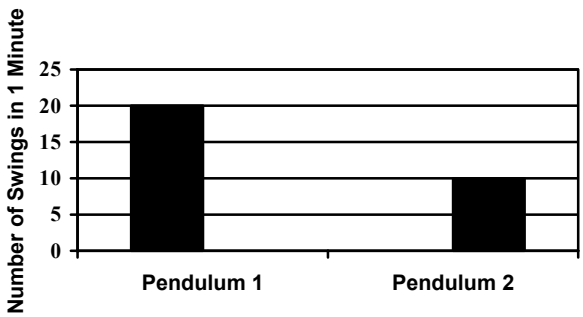
   a) They would hit the floor at the same time because they fall at the same rate.

   b) The paper clip would hit the floor first because the paper clip falls faster.

   c) The objects would bounce to the same heights because they hit the floor at the same time.

   d) The washer would hit the floor first because the washer falls faster.

3. According to the graph, which pendulum has the longest string? **Explain** your answer using the data you collected in the activity.



Assessment
10 Minutes
Key

1. D
2. A

Points
2
1
0

Question 3 Answer Rubric	Points
Correct Statement and Explanation **Correct Statement:** "Pendulum 2" has the longest string. **Explanation:** In the experiment the pendulum with the longest string had fewest swings per minute and the pendulum with the shortest strings had most swings per minute. The graph indicates that Pendulum 2 has fewer swings per minute compared to "Pendulum 1."	2
Correct Statement and Missing Explanation **Correct Statement:** "Pendulum 2" has the longest string.	1
Incorrect Answer	0