Grade Level/Course: 5th Grade Math and Science

Lesson/Unit Plan Name: Pendulums – Swinging into graphs

Rationale/Lesson Abstract: Students will make pendulums with various characteristics, taking care to measure and record their work accurately, in order to find out what variable(s) causes the pendulum to swing faster. They will make a graph on a coordinate plane showing the relationship between two variables.
This activity provides data in two variables and in two units of measure which leads to an introduction to the idea of the two kinds of variables: manipulated (independent or *x*) and the responding (dependent or *y*) variables. When graphed, a relationship can easily be seen. In this case the "rule" is difficult to derive, but the graph can easily be used to predict estimated outcomes in either variable.

Timeframe: about 5 days

Common Core State Standards in Math

5.G.1 Use a pair of perpendicular number lines, called axes, to define a coordinate system with the intersection of the lines (the origin) arranged to coincide with the 0 on each line and a given point in the plane located by using an ordered pair of numbers, called its coordinates. Understand that the first number indicates how far to travel from the origin in the direction on one axis, and the second number indicates how far to travel in the direction of the second axis, with the convention that the names of the two axes and the coordinates correspond (e.g., x-axis and the x-coordinate, y-axis and y-coordinate).

5.G.2 Represent real-world and mathematical problems by graphing points in the first quadrant of the coordinate plane, and interpret coordinate values of points in the context of the situation.

Next Generation Science Standards

3-PS2-2 Make observations and/or measurement of an object's motion to provide evidence that a pattern can be used to predict future motion. (Examples of motion with a predictable pattern could include a child swinging in a swing.)

SEP-2 Use models to describe phenomena.

SEP-3 Conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials are considered. Make observations and measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon.

Instructional Resources/Materials

For the class:
- Ball of string – strong enough to hold 3 pennies and can easily be tied.
- Roll of masking tape
- 1 timer/stop watch

For each group:
- 1 paper clip
- 1 #10 envelope
- 3 Pennies
- 1 Pencil
- 1 meter stick or tape (may be shared between groups)
- 1 pair of scissors

For each student:
- Science Journal to record the experiments

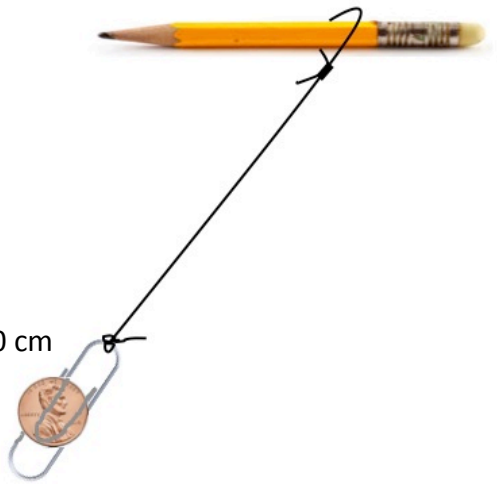
Activity/Lesson:

Day 1: Introductions to Pendulums
Pre-cut a 75 cm length of string for each group
Begin with the warm-up on page 12. Review using a centimeter ruler.

Show a model of what they will be making (penny on a string), swing it and explain that they will be making their own pendulums and doing experiments with them.
The first step is to make the pendulums. In order to compare the results we need to make sure to make our equipment the same way. Make sure students are measuring accurately.

Working in pairs, each group will need:

~75 cm of string	~20 cm (8”) of masking tape
1 paper clip	1 envelope
1 pencil	1 pair of scissors
1 penny	1 meter stick or tape



Construction:

Tie one end of the string to the paper clip
Measure 50 cm by putting the tip of the paper clip at 0 cm and folding the string over at exactly 50 cm.
Put a small piece of masking tape around the string to make a loop large enough to slip over a pencil.
Re-measure the pendulum to make sure it is 50 cm from the tip of the paper clip to the top of the loop.
Slip the penny into the paperclip.

The experiment:
Teacher: How many times do you think your pendulum will swing in 10 seconds?
Record predictions on the board.
Teacher: Let's experiment
Swing your pendulum and count how many swings your pendulum makes (called a period).
Ready set go – time 10 sec. STOP

Report out how many swings. This will probably vary.
Ask the students to talk with their elbow-partner about why their answers are so different when the pendulums were made exactly the same way. (possible ideas: counting ½ swings, holding string they could actually be swinging it more, starting the swing from different places, etc.).

Conduct the experiment with controls:

- Tape a pencil to the desk (eraser out) with their remaining piece of masking tape, so they don't accidentally swing with their arms.
- Start the swing from the same place (exactly horizontal, or even, with their desks).
- Define a complete swing, or period. It is when the pendulum comes back to its beginning point on the starting side (**a period is a motion or activity that repeats itself**).

Try again. Practice a few times; learn to count silently. Everyone should have counted 7 periods.

Everyone got the same result because our "equipment" and our experiments were the same.

Put the pendulums and pencils in their envelopes (collect now, or during transition time).

The goal in these experiments is to find out what changes we can make to cause the pendulum to swing faster or slower.

"How will we measure speed?" – counting the periods per 10 seconds

What might we do to get a different number of swings in 10 seconds?

Their predictions should include (write these on the board or on chart paper to refer to throughout this unit):

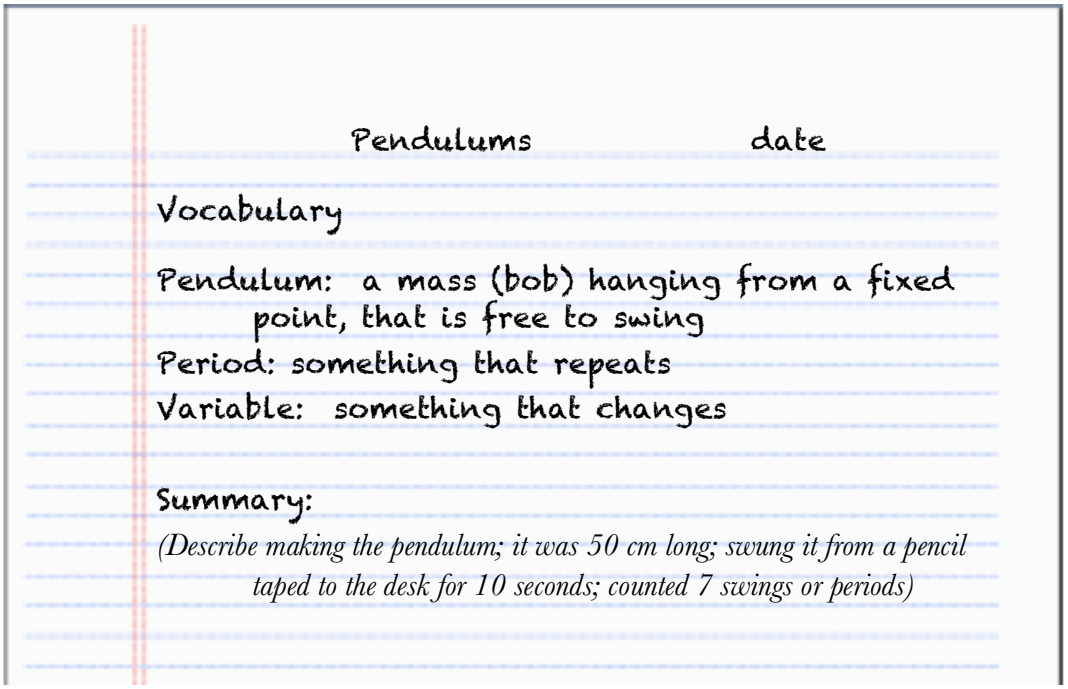
- changing the length of the string
- changing the number of pennies (the weight on a pendulum is called a bob)
- changing the release position

Things that change in an experiment are called *variables*. This comes from the word **vary**.
Ask for definitions for the word vary: (should get answers like *it change*s). The word variety also comes from vary. For the next 30 seconds, tell your elbow-partner about something that varies or that there are varieties of it. Call on a couple of groups to share-out.

In science, we use the word variable for the things in an experiment that change. In math, we use the word variable for the numbers in an expression or equation that change.

Scientists are very careful to only change 1 variable at a time. For the next 15 seconds, explain to your partner why you think they only change one thing? (if you change 2 at once, you don't know which one caused the change in the outcome). We will test some of your ideas tomorrow.

Conclude today's experiment by recording today's work in their Science Journals. Have them write the formal definitions for the vocabulary words and then write the summary in their own words.



Day 2: Changing Variables

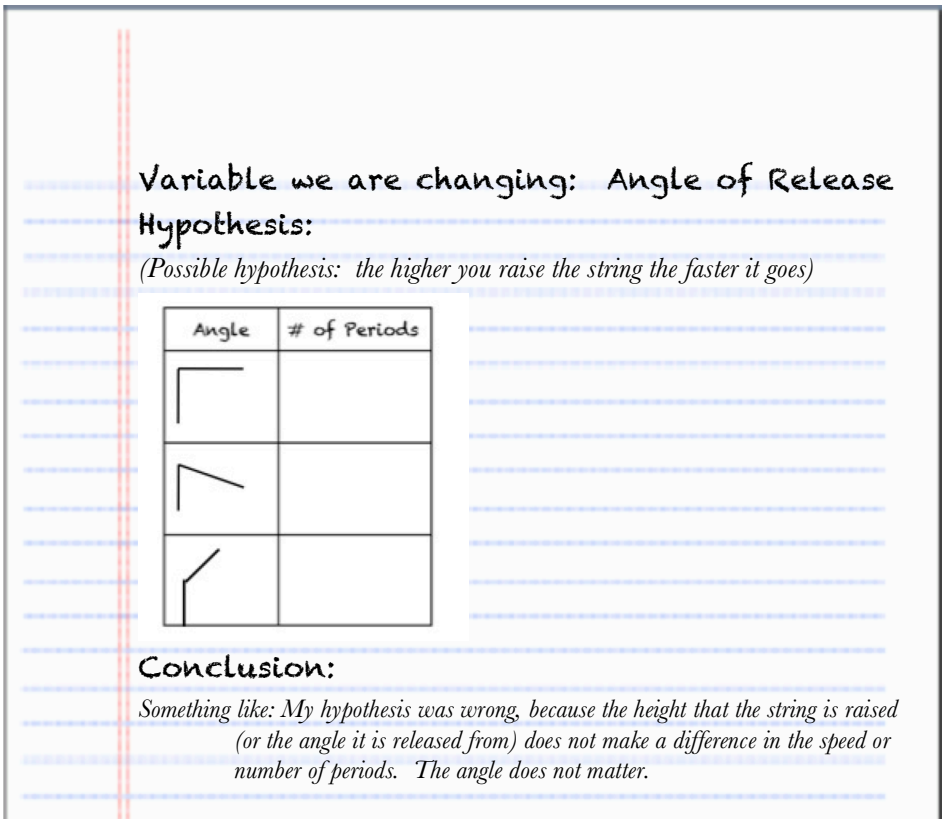
Review the possible variables.
- Release position
- Weight of the bob
- Length of the string

The easiest variable to change without changing the equipment is the angle that you start from. 3 heights or angles to release it from are shown in the sample journal entry that follows.

Write in Journal:
* The title
* The hypothesis: Talk with their partner about their hypotheses, then they write their own hypothesis in their journal.

Next, make a table with 3 lines and 2 columns labeled **angle** and **# of periods.**

They will record their results in the journal as they do the experiment.



Conduct the experiment:

1. Raise it to table height (a right angle) and count the periods in 10 seconds, record # of periods (it should be 7) record your results in your journal
2. Raise it ½ way up and count the periods in 10 seconds, record # of periods (it should be 7) record your results in your journal
3. Raise it higher than the table and count the periods in 10 seconds, record # of periods (it should be 7) and record your results in your journal

Think about your results. Are you surprised? Discuss this with your elbow-partners.

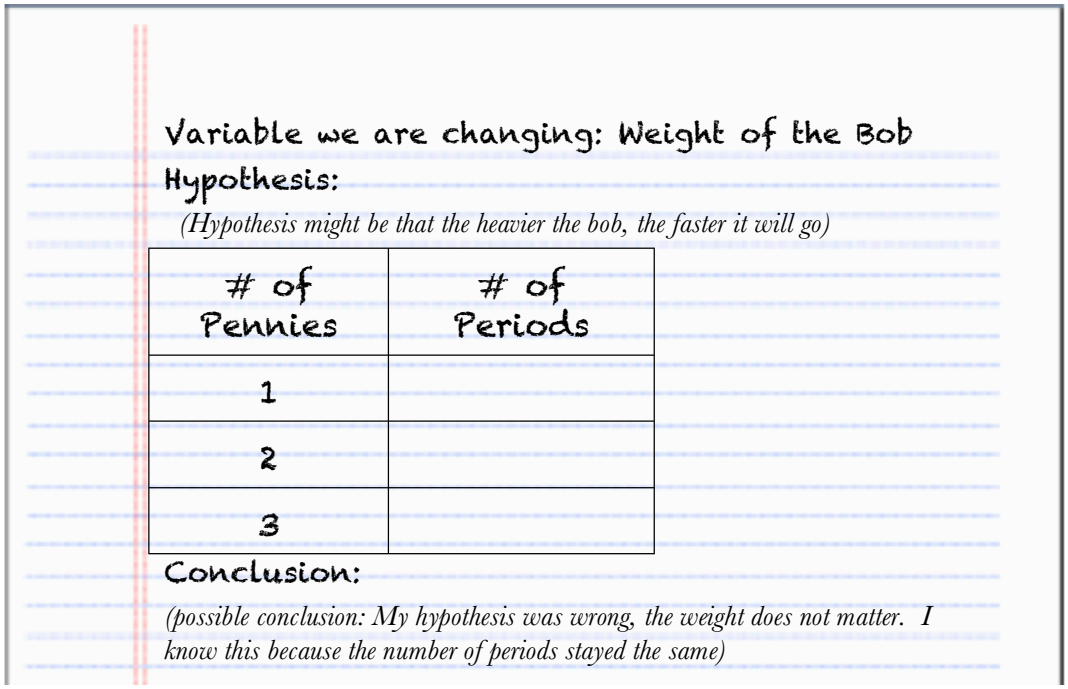
Now write your conclusion under the table in the Science Journal.

Day 3

Note to Teacher: before day three - write each of the following measures on separate index cards and put them with the materials 10, 15, 20, 25, 30, 35, 40, 50, 75, 100, 150, 175, 200 (or any other lengths you wish to try – shorter ones are much easier to deal with).

Begin the activity:
Next variable: weight of the bob
Discuss the possibilities (it will go faster or slower), how do we measure speed? It's the number of periods in 10 seconds; the more periods, the faster it is going. Then write their hypothesis in the journal and set up the new chart.

In Journal, write the title and their hypothesis.
Make the chart in the journal, so that the number of periods can be recorded as they do the experiment.



Variable we are changing: Weight of the Bob

Hypothesis:

(Hypothesis might be that the heavier the bob, the faster it will go)

# of Pennies	# of Periods
1	
2	
3	

Conclusion:

(possible conclusion: My hypothesis was wrong, the weight does not matter. I know this because the number of periods stayed the same)

1. Record periods with 1 penny (go back to releasing at table height – it didn't seem to make a difference, but we need to be very consistent and only have 1 variable change)
2. Record periods with 2 pennies
3. Record periods with 3 pennies

Discuss the results. (It should still be 7 periods in 10 seconds.)

Write their conclusion in their Journals.

Day 4: Changing the Length of the Pendulum
This part can be started on day 3 and finished on day 4 – it is time consuming to make new pendulums.

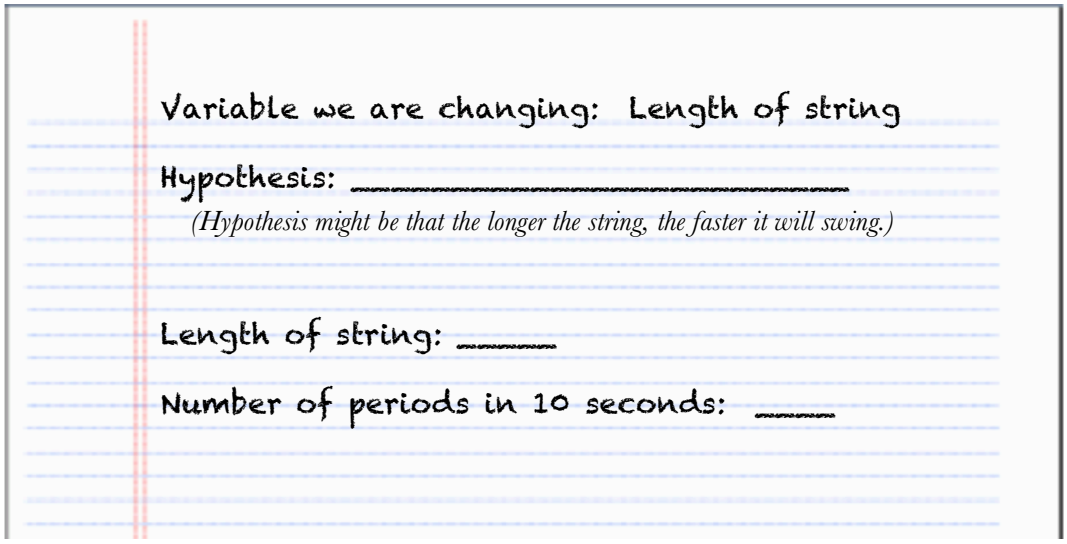
What's the last variable that we haven't changed yet? Length
Now we will have to make new pendulums. Each group will make a different length and we will compare the results.

Get:

- string
- masking tape (about 20 cm)
- scissors
- meter stick or centimeter ruler for the short lengths
- index card with the length for their pendulum
- envelope with the 50 cm string, pencil, and penny

In Journal write the title. Talk with their partner about how the length of the string might change the speed of the pendulum. Share a few ideas, then they write their own hypothesis in their journal.

Write in the length of the string for the pendulum they are making.



Construct:
Make their new pendulums and find a place to swing them (many will be too long to swing from their desks).

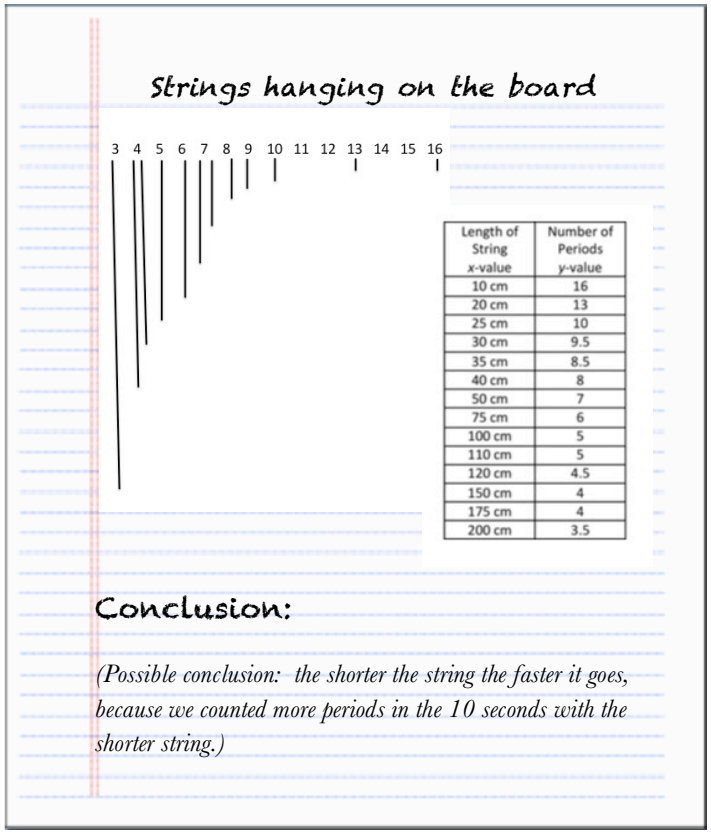
Conduct the Experiment:
Time the number of cycles in 10 seconds several times (until they get the same result several times).

Write the numbers of periods (about 2-16) across the top of the white board. Then take their strings and tape them under the number on the white board.

Draw a sketch of what is on the board, in their Science Journal. Draw this on the left page in their Journal, so that the formal graph can be on the right page and they will be easy to compare.

What do you notice? Discuss (*the shorter strings made more swings in the 10 seco*nds).

Write a conclusion in their Science Journal, under the drawing of the hanging strings. Be sure to use the word "because" in their conclusion.



Strings hanging on the board

3 4 5 6 7 8 9 10 11 12 13 14 15 16

Length of String *x*-value	Number of Periods *y*-value
10 cm	16
20 cm	13
25 cm	10
30 cm	9.5
35 cm	8.5
40 cm	8
50 cm	7
75 cm	6
100 cm	5
110 cm	5
120 cm	4.5
150 cm	4
175 cm	4
200 cm	3.5

Conclusion:

(Possible conclusion: the shorter the string the faster it goes, because we counted more periods in the 10 seconds with the shorter string.)

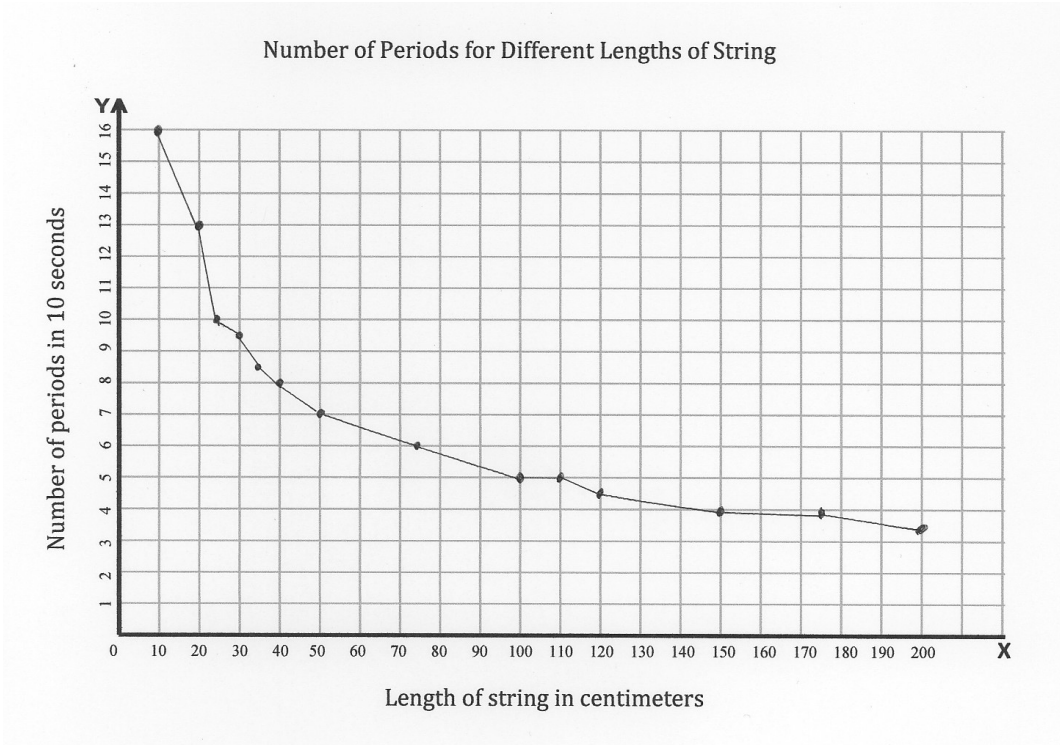
D**ay 5: Draw a proper graph of the Data**

We have a lot of data and need to make a proper graph of our results. First, let's collect the data. Each team will need to present how long their string is and the number of periods it swung. Record everyone's information (data) in a table. Each person will record all of the data in a chart (attached on page 11) in their Science Journal.

Length of String *x*-value	Number of Periods *y*-value
10 cm	16
20 cm	13
25 cm	10
30 cm	9.5
35 cm	8.5
40 cm	8
50 cm	7
75 cm	6
100 cm	5
110 cm	5
120 cm	4.5
150 cm	4
175 cm	4
200 cm	3.5

In math and science, we put the values of the variable we have changed (also called the manipulated or independent variable) on the x-axis (across the bottom), and the result (the responding or dependent variable) on the y-axis (vertically).

Be careful to have each line on the graph represent the same distance from the line next to it, although each axis may be counted differently. Count by 1 for the **seconds** and count by 10s for the **length**. (Graph is attached on page 11). *Glue these into their Journals – the table on the left page with the picture of the hanging strings, and graph on the right (facing) page.*



The graph looks different from the picture of the strings on the board because the new graph is like turning the picture on its side. It is now in the form which scientists use, with the manipulated variable (the one we changed) along the bottom (x-axis).

Assessment:
Use their journal entries as daily assessments.

Final assessment:
Review the three experiments with the students, and the original question: What causes a pendulum to swing faster or slower?
Think/Pair/Share: what variables did we change, and what changes did that make in the number of periods that the pendulum swung.
The students will then write a summary in their science journals. They should include the three experiments that were done with the pendulums, drawing a conclusion that answers the original question: what causes a pendulum to swing faster or slower as measured in periods per 10 seconds?

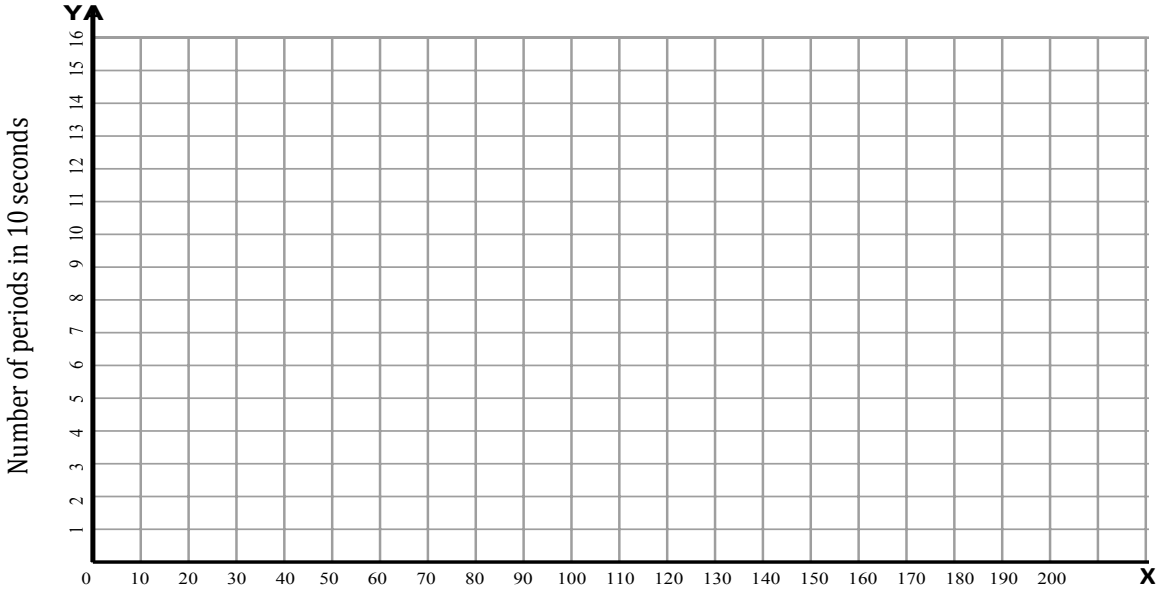
Extensions for this activity:

Interpret a graph. (5.G.2)
Estimate the number of periods, in 10 seconds, for a string length that you did not test. Using the graph from day 5, select a length on the x-axis, go up to the graphed line, then look to the left from the point of intersection, to find the approximate number of periods for that length.

Convert from seconds to minutes. (5.MD.1)
Use the table from day 5 to find the number of periods in 10 seconds for a particular length of string. Calculate the number of periods per **minute** for the chosen length by multiplying the number of periods by 6. This gives the periods per minute for that length.

Length of String in centimeters *x*-value	# of Periods *y*-value

Number of Periods for Different Lengths of String



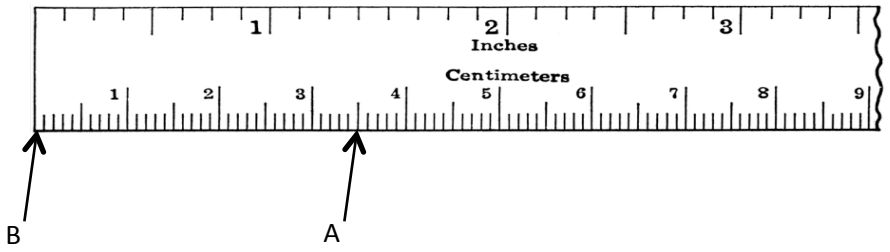
Name _____

Date _____

Warm-up for Day 1

Follow this example and mark the ruler below with an arrow and the letter.

A. Mark 3.5 cm B. Where do you put the string to begin measuring?



You try:

A. Where do you put the string to begin measuring?
B. 7 cm
C. 5.5 cm
D. 1 cm
E. 8.5 cm