Pendulum Pandemonium

Subject Area(s) Physical Science

Associated Unit None

Associated Lesson None

Activity Title Pendulum Pandemonium

Header Insert image 1 here, right justified to wrap

Image 1
ADA Description: Students Performing Experiment
Caption: Image 1: Students Recording Data
Image file name: students.jpg
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Grade Level 11 (9-12)

Activity Dependency None

Time Required
-45 minutes to build the pendulums with teacher assistance.
-45 minutes to program the NXT bricks and do the pre-activity assessment
-45 minutes to perform calculations and measurements. Interpretation of results (see worksheet attachment) can be assigned as homework or started in class if time permits.

Group Size

Four students

Expendable Cost per Group US$0 (assuming school has NXT and LEGO kits)

Summary

Each group of students will construct a LEGO Mindstorm NXT set-up that includes a pendulum and a light sensor. The light sensor will detect time instances when the pendulum's bob passes through a certain point as dips on a plot of measured light intensity. From these plots, students will measure the period of the pendulum for different lengths of the pendulum rod. Next, they will compare the experimentally determined values of the period to values calculated using a well-know formula. Finally, they will change the weight of the bob connected to the pendulum string and repeat the experiment to verify that the period of the pendulum is not affected by changes in the bob's weight. A discussion on the practical applications of pendulum technology and its history should be included as part of the post-activity assessment.

Engineering Connection

The ability to predict the outcome of an experiment is an important stepping stone in learning to apply scientific principles. The students will become familiar with the development of a theory and its experimental proof.

Pendulums have been one of the first technologies used to measure time accurately. Students will observe how the oscillations of their NXT pendulum dampen, and try to figure out ways to overcome this tendency in order to conceptually design a pendulum clock.

Engineering Category

Relates math and physics concept to engineering.

Keywords

Pendulum, period, gravity, rod, length, LEGO, experiment, bob, clock.

Educational Standards

- New York Science (Physics 9-12): Standard 2
- New York Science (Physics 9-12): Standard 1
- New York Math (9-12): Measurement Strand

Pre-Requisite Knowledge

Fractions
Square Root

Force of Gravity

Learning Objectives
After this activity, students should be able to know what a pendulum is, how it works, and how to calculate the period. They will also understand how a clock using pendulum technology works.

Materials List
Each group needs:
- One complete LEGO Mindstorm NXT kit, 3 extra lamp bricks, and extra standard LEGO bricks for the construction of the base
- Computer with NXT 2.0 software installed
- Ruler or tape measure
- Calculator

To share with the entire class:
- Bag of mixed LEGO bricks
- Tape
- Roll of string
- Scissors

Introduction/Motivation

Today we are going to conduct a simple experiment and see if we can predict its outcome.

Using physical laws, it can be shown that the period T of a pendulum (time it takes to complete one sweep and return to its original position) is given by the formula $T=2\pi*\sqrt{(L/g)}$. In this expression, L denotes the length of the pendulum (approximated as length of the string from the pivot point to where it is attached to the bob) and g denotes the acceleration of gravity, approximately 9.81 m/s^2 on earth.

We will build an experimental setup that can measure the period of a pendulum. Using this setup, we will determine the period of the pendulum for three different lengths.

In our experimental setup, the swinging pendulum will interrupt the light beam between a bank of small lamps and an NXT light sensor. Each interruption of the light beam will

cause a drop in the amount of light recorded by the sensor. The light intensity as a function of time will be plotted for us by the NXT Data Logging software.

We will obtain the period of oscillation for three different rod lengths and examine whether the experimental results match our theoretical calculations.
We will then repeat the experiments using a different weight, by adding an extra brick to the pendulum bob. We want to show that the period does not change for each length, thus establishing that the period of the pendulum is independent of its weight.

Lastly, we will have a discussion on the practical applications of pendulums, such as time keeping.

IMAGE Insert Figure 1 here, centered

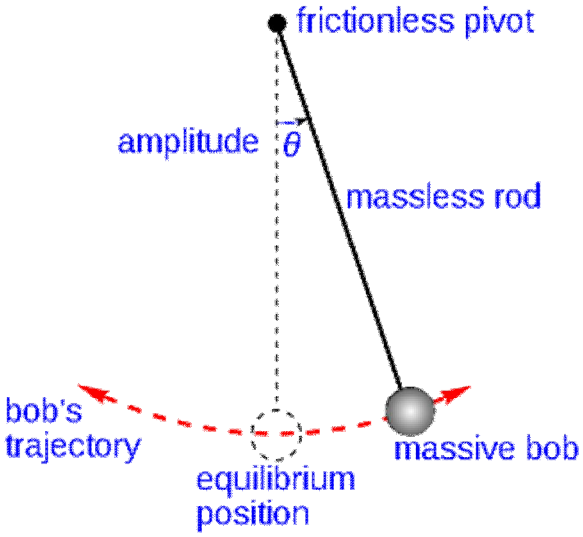

Figure 1
ADA Description: Pendulum terminology
Caption: Figure 1: Pendulum layout and terms
Image file name: 637px-Simple_gravity_pendulum.svg.png
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Vocabulary/Definitions

Word	Definition
pendulum	A body suspended from a fixed support so that it swings freely back and forth under the influence of gravity, commonly used to regulate various devices, especially clocks. (from www.thefreedictionary.com)
period	The time interval between two successive occurrences of a recurrent event or phases of an event. (from www.thefreedictionary.com)
pivot	• A short rod or shaft on which a related part rotates or swings • The act of turning on or as if on a pivot. (from www.thefreedictionary.com)
bob	The mass attached to the end of the pendulum arm.

Procedure

Before the Activity

- Teacher should build a pendulum and run the experiment on her own.
- Before class, rulers, kits, calculators, and computers should be made available to each group.
- Tape, scissors, bag of LEGO parts need to be placed in an accessible location for the entire class.
- Make sure NXT bricks have power and their memory is cleared, with NXT2.0 Firmware uploaded.

With the Students

1. Construction Phase:

   Assist the student groups in building the pendulum setup in the images below (Images 2—9). The layout can be altered to use available bricks. The rules are that the light sensor should be placed level with the bank of lamps. The pendulum, when moving, should cross the imaginary line between the lamps and the sensor. This will decrease the amount of light recorded by the light sensor. The NXT data logging software will show a drop in the light level recorded by the sensor.

   Four elevating blocks (stack of four black bricks in images) allow three positions for the light sensor and lamps, thus resulting in three measurements for lengths and periods. The tape is used to make sure the end of the string doesn't slip off the pulley.

IMAGE Insert Image 2 here, centered

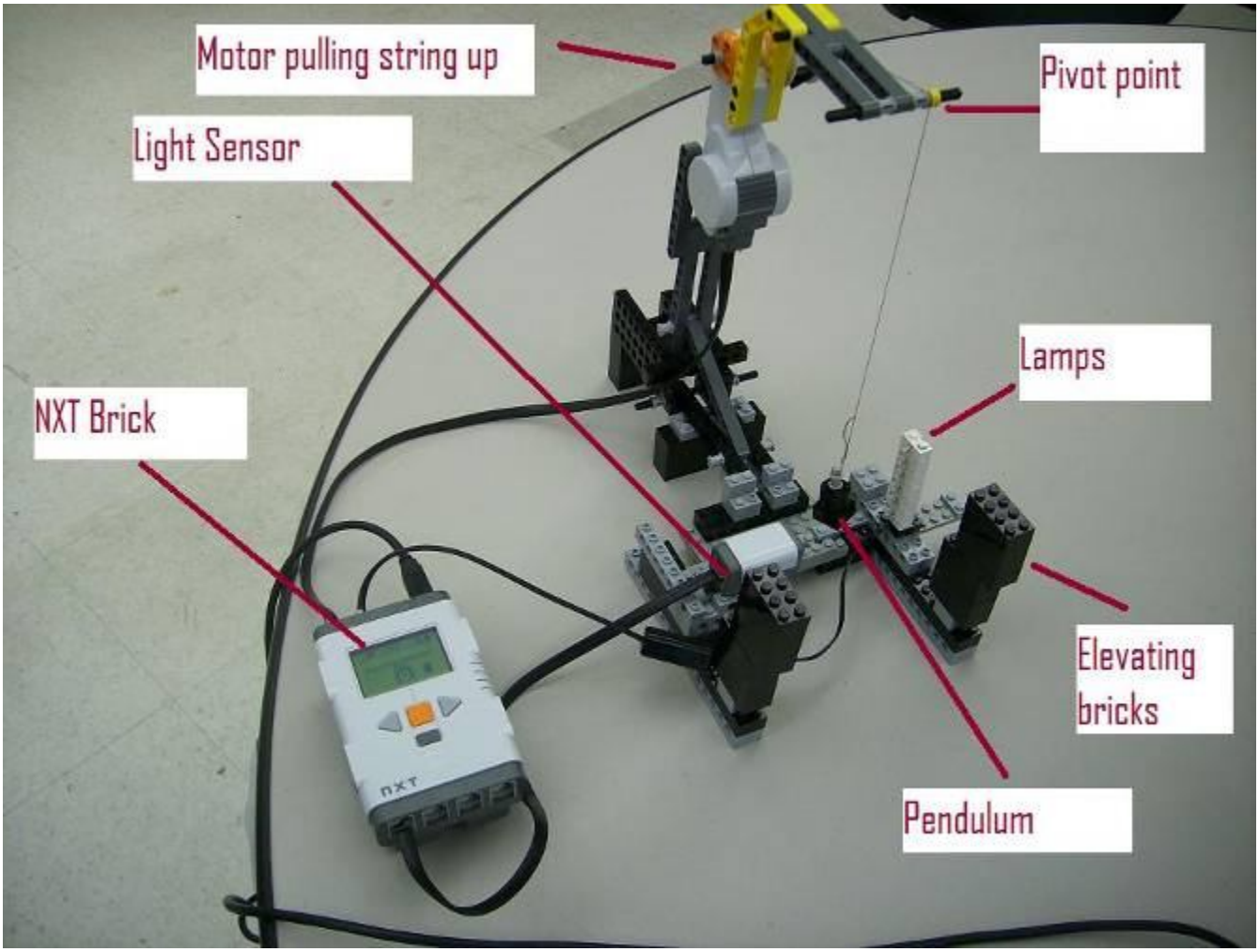

Image 2
ADA Description: Overall
Caption: Image 2: Annotated view of Setup
Image file name: overall.jpg
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IMAGE Insert Image 3 here, centered

Image 3
ADA Description: Cables
Caption: Image 3: Cable Connections to Brick
Image file name: cable connections.jpg

IMAGE Insert Image 4 here, centered

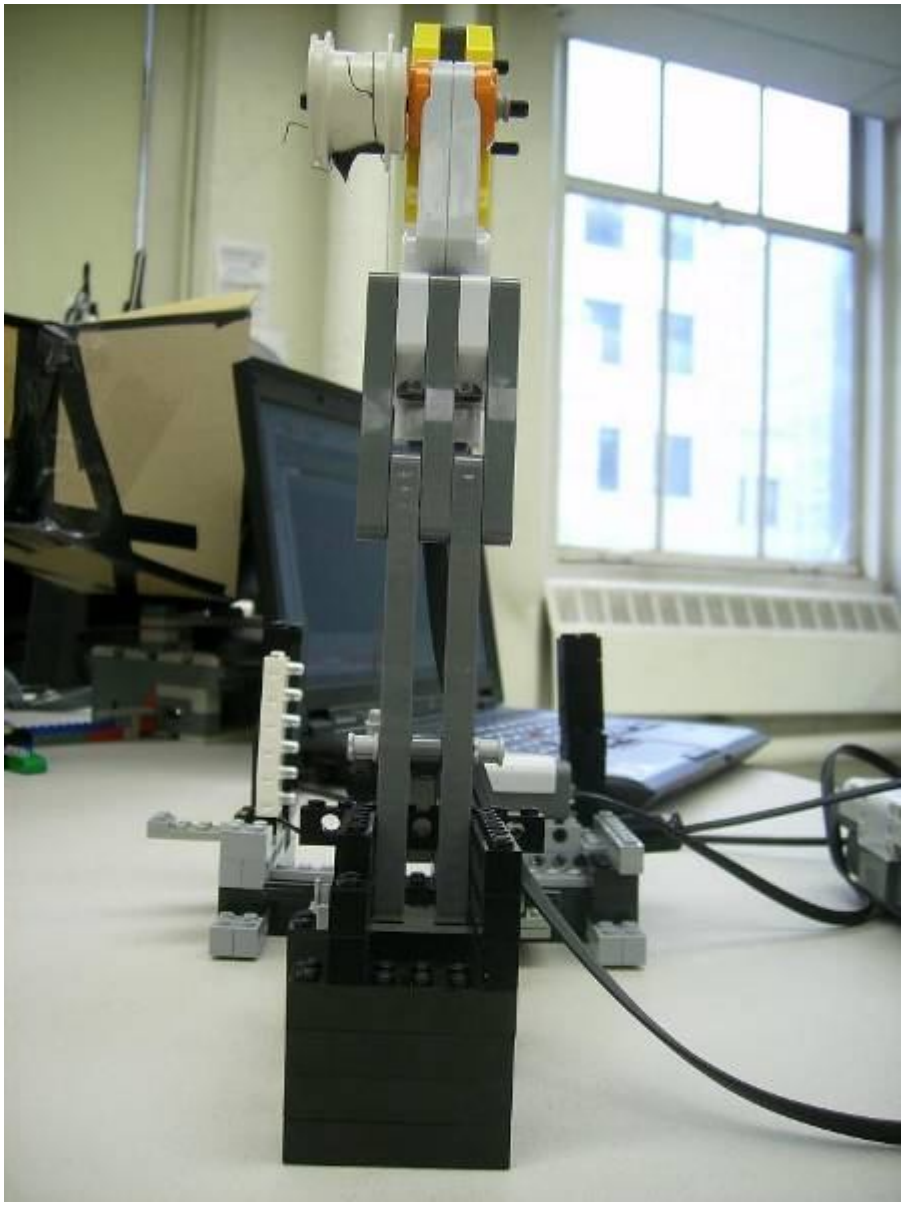

Image 4
ADA Description: Rear View
Caption: Image 4: Rear View Showing Pulley Arrangement
Image file name: rear view.jpg

IMAGE Insert Image 5 here, centered

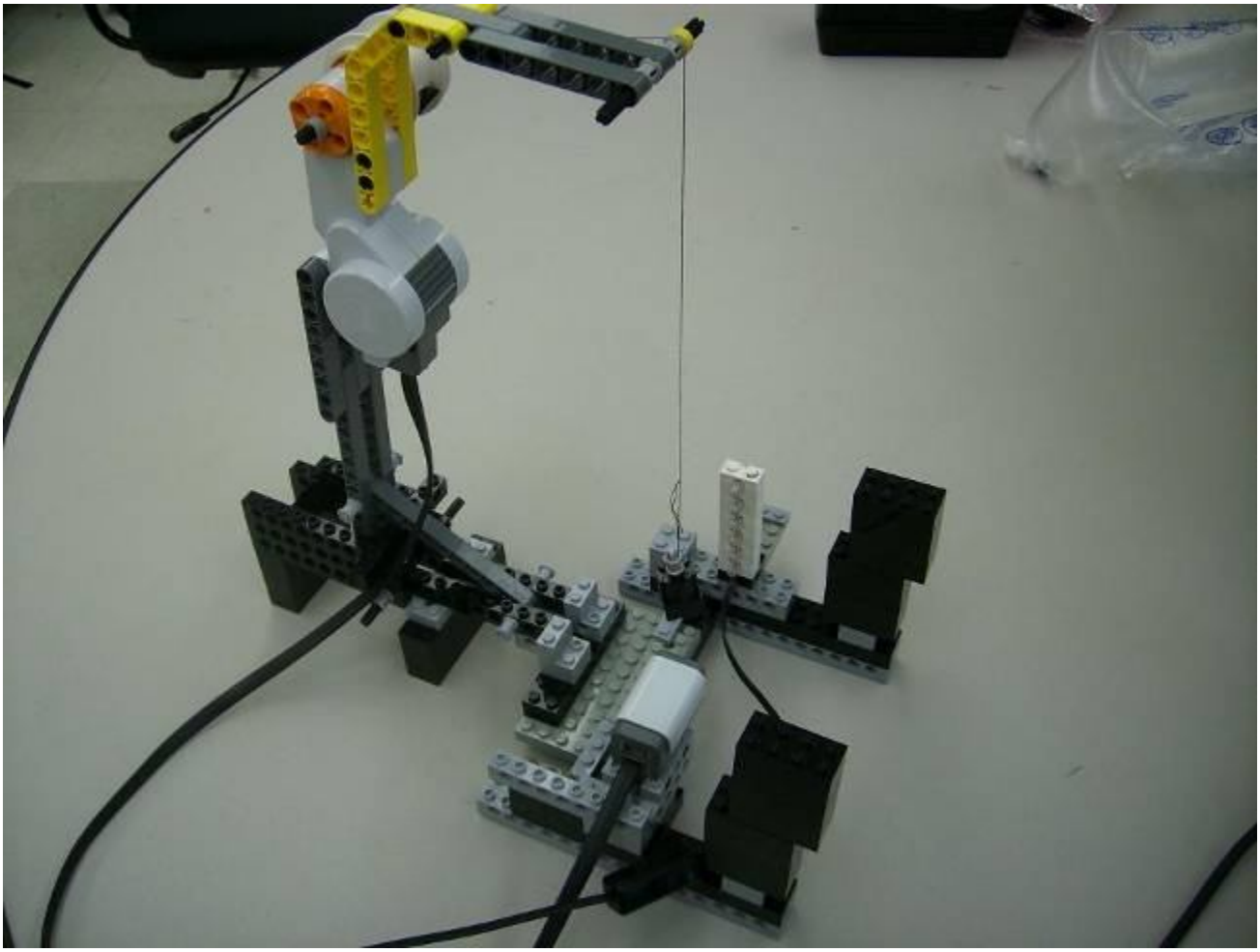

Image 5
ADA Description: Structure
Caption: Image 5: View of Structure
Image file name: structure.jpg

IMAGE Insert Image 6 here, centered

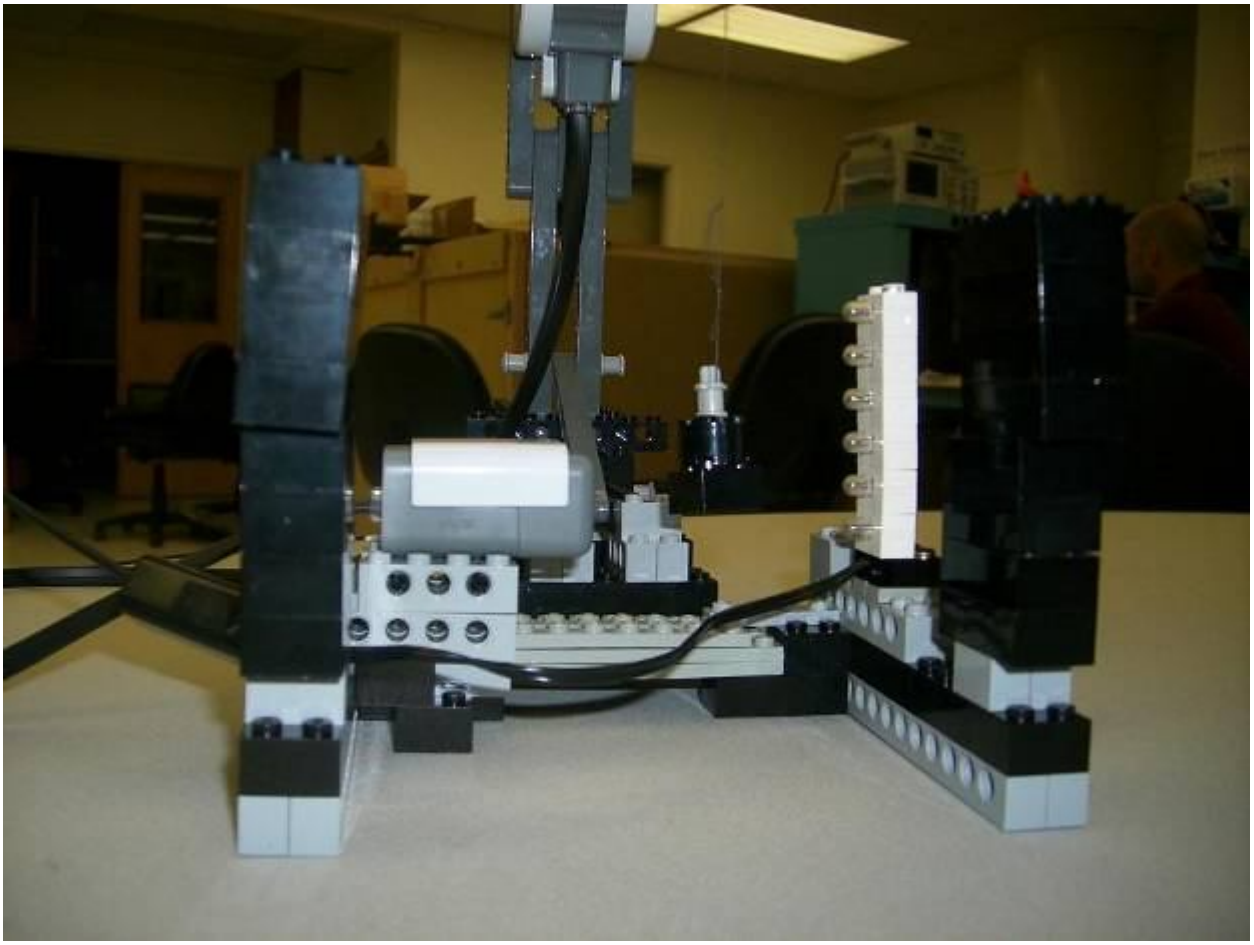

Image 6
ADA Description: Close-up Base
Caption: Image 6: Close-up on the Base
Image file name: base area close up.jpg

IMAGE Insert Image 7 here, centered

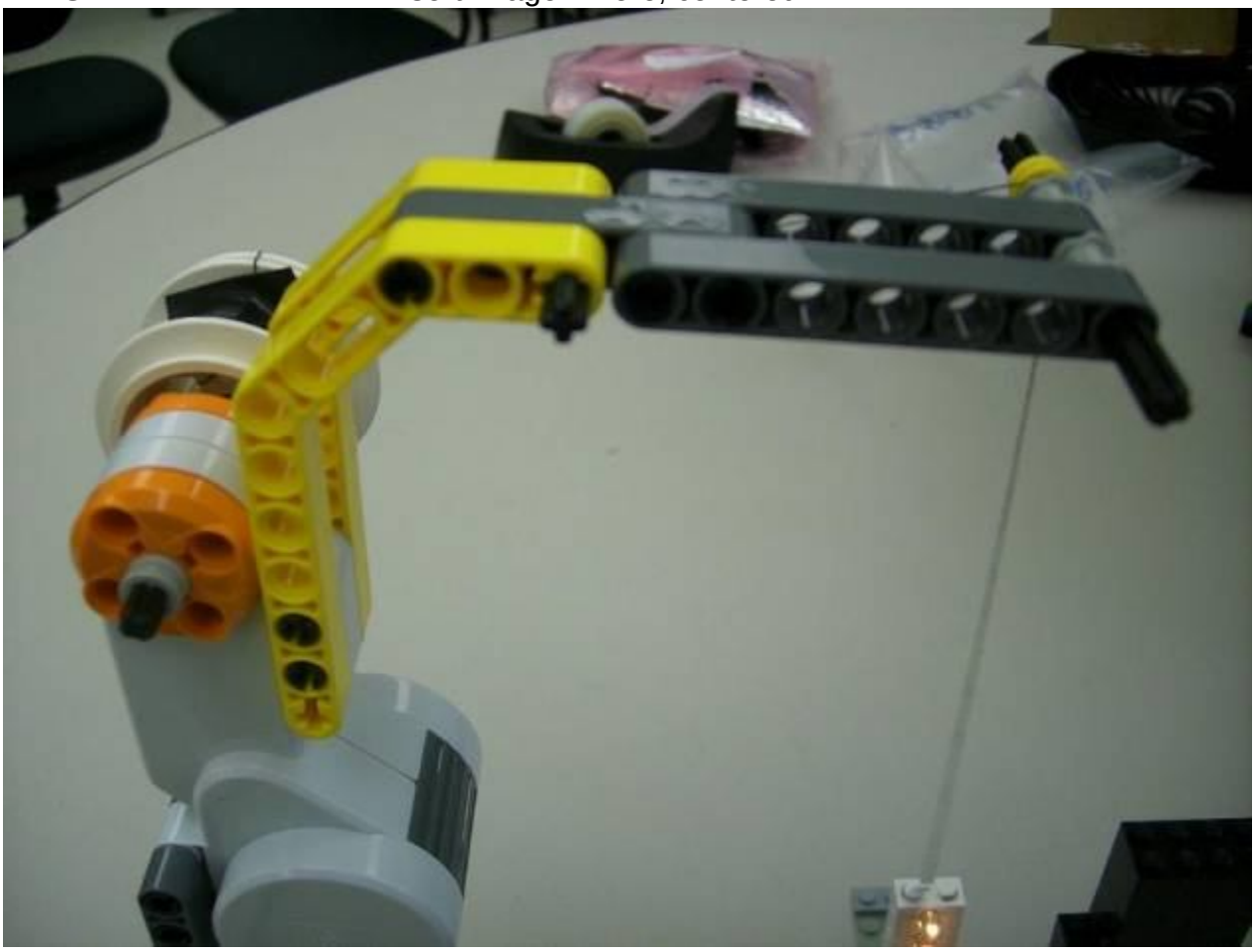

Image 7
ADA Description: Pivot
Caption: Image 7: Close-up on motor and pulley system
Image file name: pivot.jpg

IMAGE Insert Image 8 here, centered

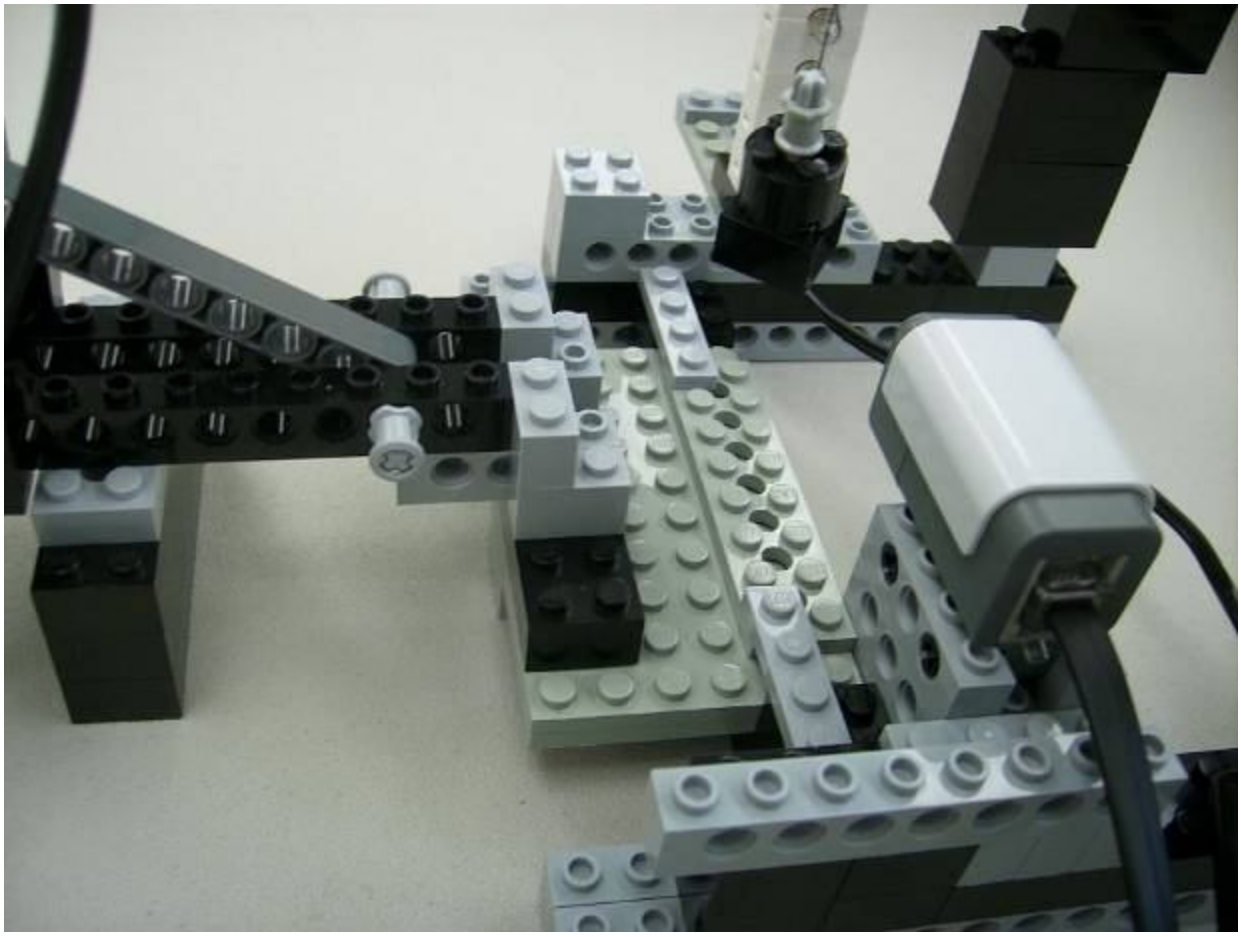

Image 8
ADA Description: Sensor
Caption: Image 8: Sensor Mounting Detail
Image file name: sensor detail.jpg

IMAGE Insert Image 9 here, centered

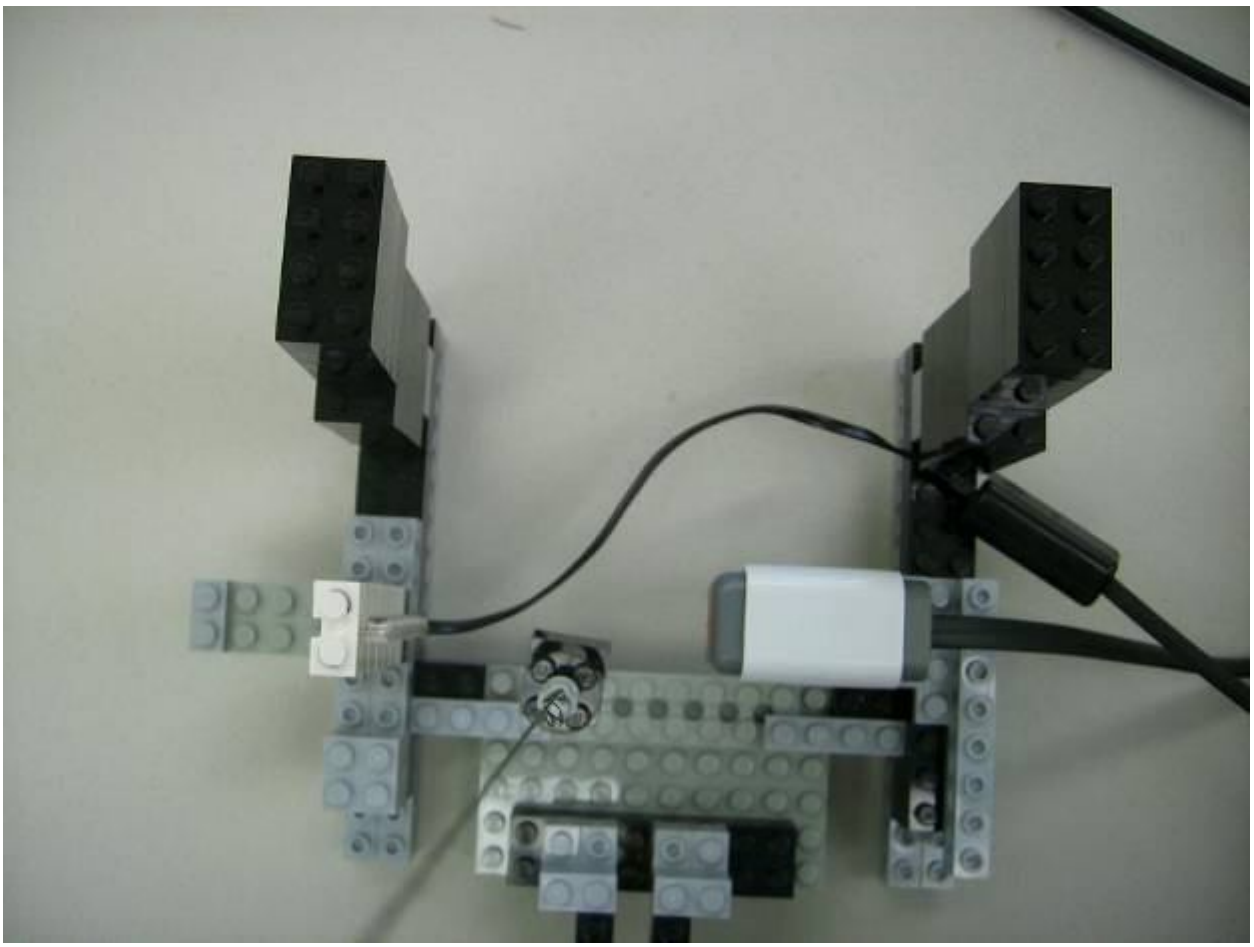

Image 9
ADA Description: Base from Top
Caption: Image 9: Top View of Base Area
Image file name: sensor from top.jpg
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2. Programming Phase

Create the simple three-block program outlined in Figure 2. The first block lights up the lamps, the second block reads data in the NXT Data Logging module, and the third block raises the pendulum by a set amount.

IMAGE Insert Figure 2 here, centered

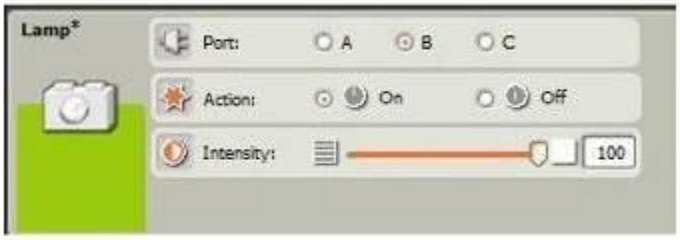

Figure 2
ADA Description: NXT Program Structure
Caption: Figure 2: The Programming Blocks
Image file name: NXT programming.jpg

3. Prediction Phase

Have the students:

Set up the experiment without using any of the elevation blocks, making sure the pendulum swings between the lamps and the light sensor. Record the length of the rod.

Run the program but don't bother collecting data or swinging the pendulum. Last instruction in the program we wrote will elevate the pendulum by shortening the string. Record the new length of the string from the pivot to the pendulum. Repeat once.

Now we have three lengths of the pendulum "rod". Have the students calculate the periods using the formula provided in the introduction, $T=2\pi*\sqrt{(L/g)}$.

4. Data collection phase

Have the students:

Set up the experiment without the elevation blocks, making sure that the same initial length as in the previous step is used. Swing the pendulum and run the program. Collect the data using the NXT data logging module. Change the color of the graph in the plot. Make a note with the color picked and the pendulum length to which it corresponds.

The program will automatically elevate the pendulum by spinning the pulley. This will shorten the length of the pendulum's arm. Elevate the light sensor and the lamp block using the elevating bricks such that the pendulum's bob again crosses the line between lamps and light sensor.

If due to variations in experiment set-up the sensor and the lamps do not come level with the pendulum using the block of four standard bricks, vary the number of bricks or use other LEGO pieces to elevate the sensor and lights as needed. Run the program again and change the color of the graph. Run the program a third time.

IMAGE Insert Figure 3 here, centered

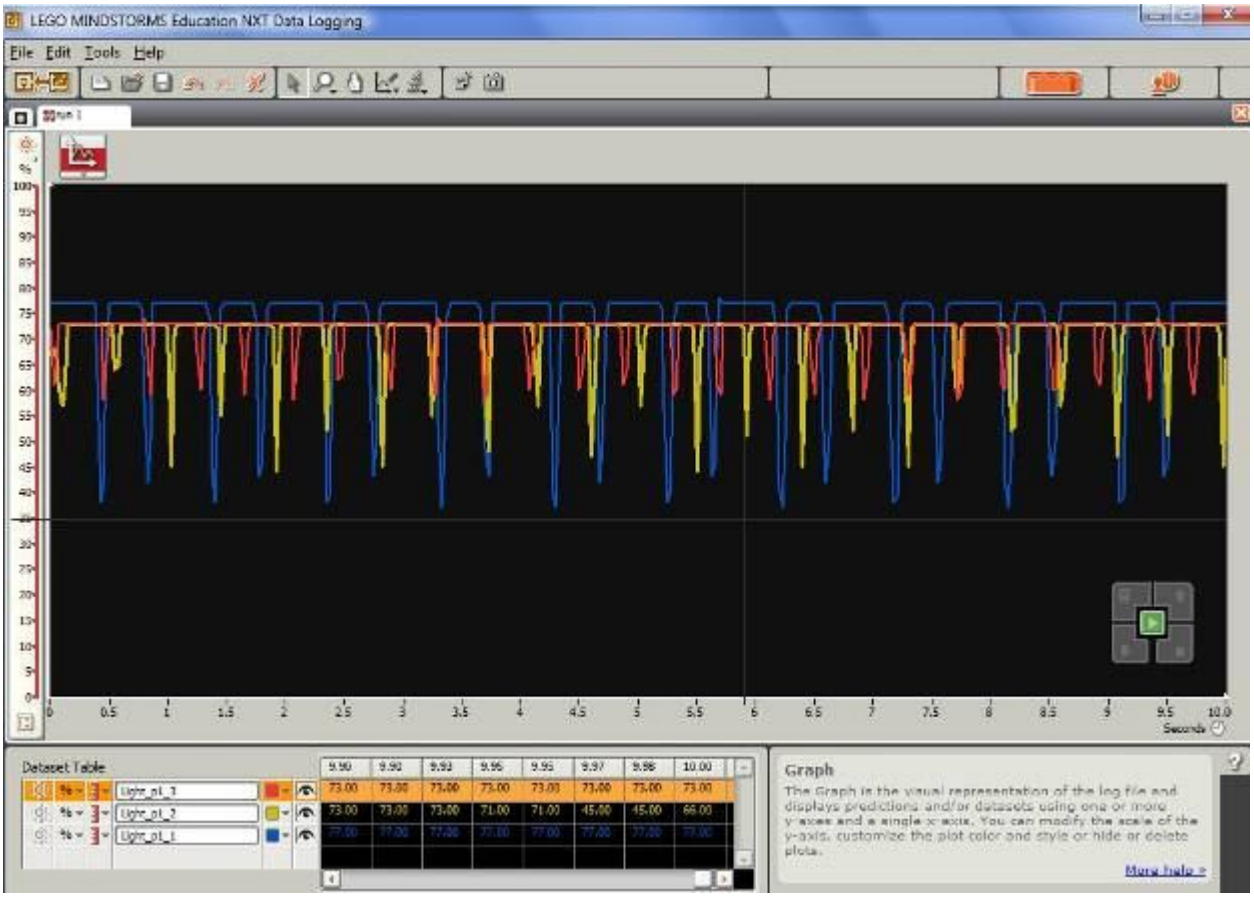

Figure 3
ADA Description: Data Example
Caption: Figure 3: Data Screen Cap
Image file name: sensor from top.jpg

IMAGE Insert Image 10 here, centered

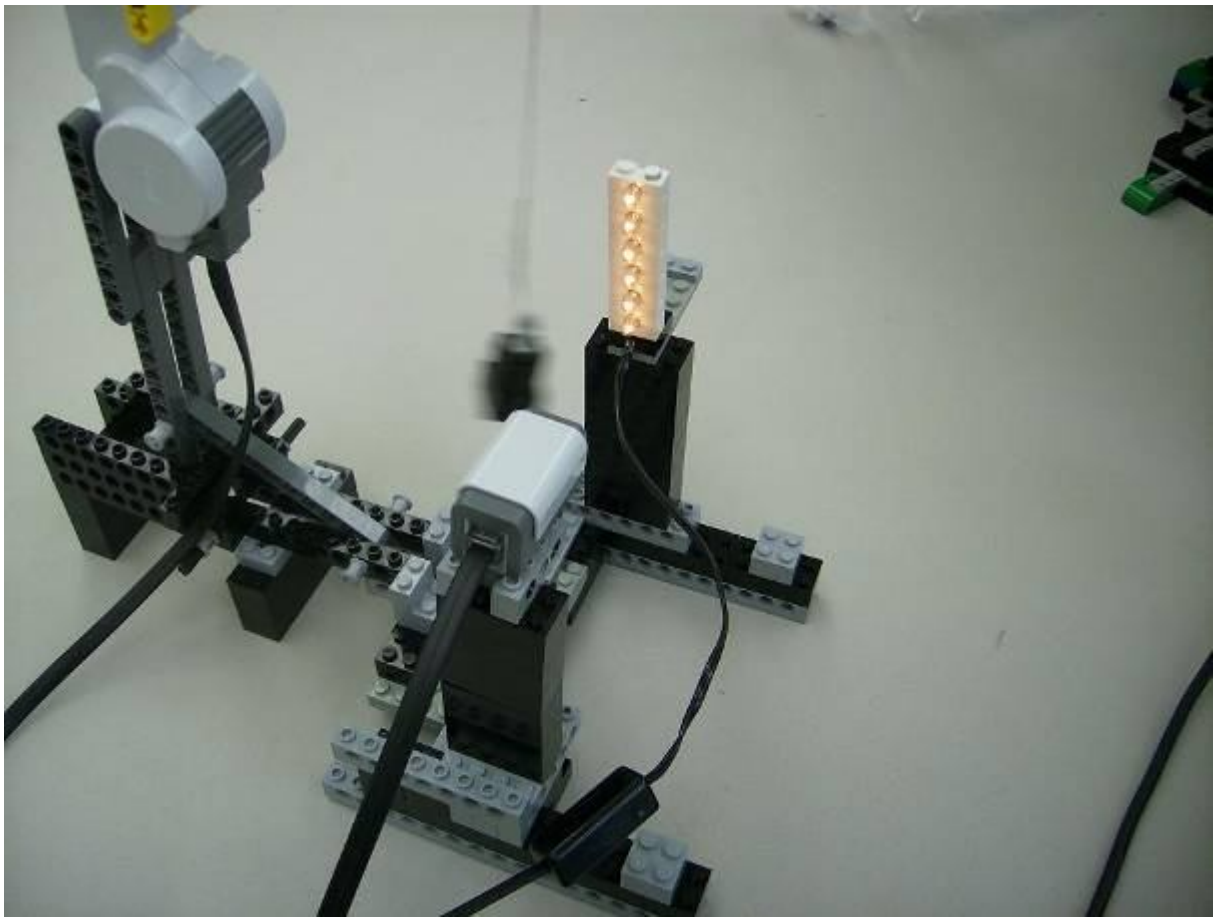

Image 10
ADA Description: Pendulum Swinging
Caption: Image 10: Pendulum in Action
Image file name: action crossing sensor.jpg
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5. Experimental and theoretical comparison

We will attempt to gauge the students' understanding of the pendulum's operation and of the data collection process. Ask whether the period for each rod length is the time between two spikes or twice that amount. Make sure they understand that the value of the period is twice the time between spikes. Have the students record multiple half-period values for each length and then average them to minimize any errors. Have them record these values in the activity sheet and compare them to the corresponding values calculated using the formula.

Repeat the experiment adding pieces to the pendulum to make it heavier. Verify that the period doesn't change.

Attachments
Results_and_Analysis_Questions_Worksheet.doc
Results_and_Analysis_Questions_Worksheet.pdf

Safety Issues
Make sure to lecture students on scissors safety prior to allowing them to cut strings.

Troubleshooting Tips
If program cannot be uploaded, erase all data from the brick's memory using the NXT software.

Investigating Questions
Would a pendulum swing in a similar manner if it were placed on the International Space Station?

Would the pendulum period be the same in a moving elevator?

Assessment

Pre-Activity Assessment
Ask students what factors might determine the period of a pendulum.

Activity Embedded Assessment
Ask students if the period is the time between two spikes or three spikes on the graph.

Post-Activity Assessment
Ask students to fill in the Results and Analysis Worksheet, listed in the attachments section.

Activity Extensions

1. Pendulum clocks

Discuss the practical uses of pendulums with the students. Start with the history of pendulum clocks and then proceed to explaining “what makes them tick”. Refer to the links in the references section. Ask the students about possible power sources to counteract the oscillations dampening over time due to friction. Make sure you put the discussion in historical context, by focusing the discussion on mechanical power sources like springs and weights. Have the students submit sketches of their pendulum clock designs. Ask the students to answer, based on the period of the pendulum, how many beats per minute the NXT pendulum would count, assuming it were used as a clock. The formula for number of beats is 60 (seconds) / period (seconds).

2. Importance of accurate time keeping devices

Discuss the implications of accurate timekeeping on the progress of science, technology and civilization in general. Explain why pendulum clocks went out of common use after World War 2.

Activity Scaling

None

Additional Multimedia Support

None

References

http://en.wikipedia.org/wiki/Pendulum

http://www.aerospaceweb.org/question/astronomy/q0227.shtml

http://en.wikipedia.org/wiki/Pendulum_clock

http://electronics.howstuffworks.com/gadgets/clocks-watches/clock.htm

http://www.emsc.nysed.gov/ciai/mst/sci/ls

http://cache.lego.com/downloads/education/9797_LME_UserGuide_US_low.pdf

Other

None

Redirect URL

http://gk12.poly.edu/amps/

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