CCMR Educational Programs

Title:	**Energy and the Pogo Stick**
Date Created:	Augist 2006
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Appropriate Level:	High School Regents Physics
Abstract:	An essential part of introductory physics is an understanding of the many forms of mechanical energy and the conversion of one form into another. Through quantitative measurement of pogo stick motion, students will study these topics for an elastic object. Concepts that are covered include Hooke's Law, gravitational potential energy, elastic potential energy, and conservation of energy.
Time Requirement:	Approximately one hour
NY Standards Met:	Process skills: M1.1, M2.1, M3.1, S2.1, S2.3, S3.1, S3.3, 4.1i, 4.1ii, 4.1iii, 4.1v. Performance indicators: 4.1a, 4.1b, 4.1c, 4.1d, 4.1e, 4.1f, 4.1h, 5.1m, 5.1o.
Sections to Document:	1) Teacher Section 2) Student Section
Equipment/Materials List:	Pogo sticks (one for each group of 5 to 6 students) 30-centimeter rulers taped to blocks (one for each group) Meter sticks (one for each group)

TEACHER SECTION

Objectives:

1) Provide practice in using and understanding the following equations:

   $F=kx$, $PEs=\frac{1}{2}kx^2$, $PEg=mg\Delta h$

2) Help students visualize and understand energy conversions.

3) Highlight the difference between ideal calculations and real world results.

4) Provide an enjoyable teamwork setting for learning physics.

5) Give students an opportunity to apply problem-solving skills.

Class Time Required:

About one hour. Can be easily subdivided into two separate sections.

Teacher Preparation Time:

Very minimal, less than 15 minutes.

Materials Needed:

1) Pogo sticks (one per 5 or 6 person group)
   - These can be purchased cheaply at yard sales. Students may also have some at home that they may like to bring in and test.
   - Do not use pogo sticks that are made for little children. The springs will not be stiff enough, resulting in erroneous data and possibly destroying the pogo sticks as they bend under the weight!

2) One 30-centimeter ruler per group, attached to a block or book as shown below.

3) Meter sticks (Note: make these available for student use in Section One, only. Meter sticks are hazardous for use in Section Two.)

<u>Tips for Teachers</u>: (The notes below closely follow the student instructions.)

A) Introduction

I like to start this lab by taking my students outside to a level blacktop sidewalk where they can take the opportunity to play with the pogo sticks. It's surprising how few students have actually jumped on a pogo stick before! Talents will vary widely! As they jump, have them identify the forms of mechanical energy that they see, namely kinetic, gravitational potential, and elastic potential energy. Students may also note the loss of mechanical energy to friction or internal energy.

> **PLEASE NOTE: For safety reasons, this is the only time that I let students freely jump on the pogo sticks! Jumping on pogos indoors is unsafe because classroom floors are often too slippery, there are usually too many hazards inside schools, and the rubber stoppers on the bottoms of the pogo sticks are usually too worn to be safely relied upon.**

After a few minutes, I relate the following story. (Keep in mind that I've already taught the equations for energy and introduced the concept of energy conversion and conservation.)

> "When I first thought of using pogos for a lab, I divided students into teams of two, one person jumping on the pogo, the other following after measuring how far the pogo is compressed at the bottom of the jump and how high the jumper went at the top of the jump. We then calculated the potential energy stored in the spring and the energy against gravity at the top. What do you think we found?"

With a little guidance, students usually correctly deduce that the potential energy stored in the spring was far less than the potential energy against gravity. In other words, the students' bodies were providing much of the energy that became gravitational potential energy, not just the pogo's spring. That is why, in the rest of the lab, the person on the pogo stick must act like 'dead weight', not adding anything to the motion of the stick.

B) Section One: Finding the Spring Constant

- I do <u>not</u> provide students with guidance on how to do this step! Instead, I let them work independently on it as a group problem-solving exercise. Usually, they eventually come up with a solution in which one of the students stands on the pogo stick. Knowing the student's weight, which can be converted to newtons, and somehow measuring the change in the spring's length, the students can thereby calculate the spring constant. This is an opportunity to reinforce the relationship between stress and strain.

- Spring constants for pogo sticks vary, but seem to average around 10,000 newtons/meter. On first glance, this will seem like a large number to the students. Upon further reflection, however, it is clear that it would indeed take a lot of force to push in one of these springs a whole meter!

- Accuracy on this step is vital.

- Be sensitive to student worries about others' knowing their weight. Usually, at least a couple of students in each group will not mind.

- Whenever a student gets on a pogo, be sure that he or she is spotted by two other students, one on each side gently providing support on the shoulder and keeping the person upright.

C) Section Two: Energy Determinations

A) I begin this section by going through the entire process as a demonstration with one of the groups as the other groups observe. The other groups then attempt the procedure with my active guidance.

B) Here is how I divide up the roles:

1. The 'rider'. This person just needs to stand on the pogo, without helping it go up or down. Usually, it's best to have one of the smaller students play this role.

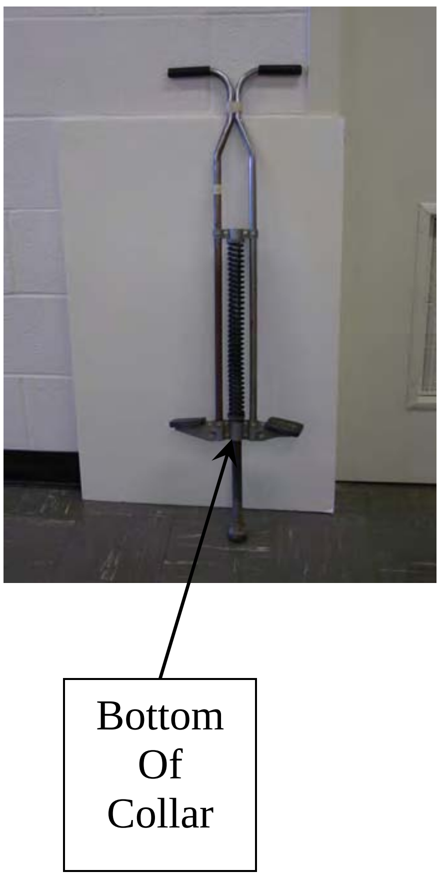
2. Two 'boppers'. These are the spotters who gently push the rider up and down. Usually, larger students are best suited for this role. I find that it works best if a bopper stands on each side of the rider, with his or her one hand on the rider's shoulder and the other on the rider's hand positioned on the pogo's handles. Emphasize safety first and that an 'aggressive' bopping does not result in better data. Keeping the rider pointed in the correct direction is an important challenge.

3. Two 'measurers'. Their role is to get down on the floor and measure the height of the bottom of the collar at its lowest point and its highest point. (I'll explain later how to make these measurements.) The measurers need to lie down on the floor so that they can make accurate measurements without parallax error. Also, they should be located several feet away from the pogo so that they are safely out of range if the pogo happens to kick outward at any point.

C) Basic procedure

1. With the active spotting of the boppers, the rider gets on the pogo stick, facing the ruler and the measurers. The block with the 30-cm ruler attached should be placed on the floor in front of the pogo stick such that the measurers can easily read it. Do not use a meter stick for this step! Its height could be hazardous to the rider.

2. The measurers get down on the floor several feet away from the bottom of the pogo, with their eyes at the height of the pogo stick's collar. It's easiest to define all measurements as the distance from the floor to the bottom of the collar. The diagram to the left indicates this point.



3. When everyone is ready, the boppers should, in synchrony, push the rider up and down. (Do not push so hard that the bottom of the collar hits the bottom of the pogo, which emits an audible click.)

4. After a few oscillations, one of the boppers should say "1, 2, 3" in rhythm with the motion. After the downward push on three, the boppers should allow the rider to move upward freely, being pushed up only by the force of the spring. Of course, the boppers need to guide the rider so that he or she does not fall!

5. One measurer will be assigned the task of measuring how low the collar goes on the last downward push (#3) and the other will measure how high the collar comes back up afterwards. The first measurement is called the 'low'; the second is called the 'high'.

6. Repeat three times. The measurers might need a little guidance in order to complete the task accurately.

7. At some point, the students need to measure the height of the collar above the floor when the rider is not on the stick. This is called the 'uncompressed height'.

D) Typical results: note that the teacher might want to leave the derivation of how to calculate ‘x’ and ‘Δh’ up to the students rather than give it to them as I do below.

Data:

Collar Location	Trial #1	Trial #2	Trial #3	Average
Uncompressed Height (m)				*.236*
Low (m)				*.136*
High (m)				*.223*

x = change in spring length = uncompressed height – low = ______*.100*___ m

Δh = height gained after final compression = high - low = _____*.087*___ m

Calculations:

1) Potential energy stored in the spring: $PEs = \frac{1}{2}kx^2$

PEs= ½ (10,500 N/m) (.100 m)² = 52.5 J

(Results are usually about this or a little greater in magnitude.)

2) Potential energy against gravity: $PEg = mg\Delta h$

PEg= (534 N) (.087 m) = 46.5 J

(Note that we used the weight in newtons for ‘mg’.)

3) % energy converted: PEg/PEs x 100%

PEg/PEs x 100% = (46.5 J/ 52.5 J) x 100% = 88.9%

(Results are usually in the 80 to 90% range. A couple groups each year get results over 100%, which is a perfect opportunity to talk about perpetual motion machines!)

D) Answers to the questions

1) When you calculated "% energy converted", why was the answer not 100%?

Friction or inaccurate or imprecise measurements

2) If a squeaky pogo stick were oiled, what would happen to your results?

% energy converted should increase

3) Suppose your group had used a heavier person on the pogo stick when finding the spring constant in Section 1 of the procedure
.

a) What effect would this have on your calculation of the spring constant, 'k'?

None. The spring constant is determined by the spring itself.

b) What effect would this have on the calculation of change in spring length, 'x'?

It would be greater.

4) Describe the energy transformations that happen as a person hops freely on a pogo stick.

PE stored in the spring becomes kinetic energy of the rising pogo and rider which becomes PE against gravity.

5) When this lab was originally designed, students jumped around freely on pogo sticks while others measured how high they jumped. They then calculated the % energy transferred and got results of up to 600%. How is that possible? Where did the extra energy come from?

It wasn't just the spring providing the energy against gravity.
The jumpers themselves were doing work as well.

STUDENT SECTION

Energy and the Pogo Stick

Name ______________________________

A) Introduction

Energy comes in many forms, some of which you have already studied in your physics class. Behind this diversity is the unifying concept of the conservation of energy, which states that energy cannot be created nor destroyed. Energy can, however, be converted from one form to another and transferred from one object to another. In this lab, we will be using pogo sticks to study energy transformations.

B) Section One: Finding the Spring Constant

Your group has been assigned a pogo stick. Find a way by which you can use the equation F=kx (Hooke's Law) to determine the value of the pogo's spring constant 'k' in newtons per meter. Before making any measurements, discuss your plan with your teacher! Use the space below to record your work.

Spring constant (k) = ________________N/m

C) Section Two: Energy Determinations

In this section, one of your group's members (the 'rider') will stand on the pogo stick while two other members (the 'boppers') will push the rider up and down. Two other members (the 'measurers') will take measurements that will allow you to calculate the potential energy stored in the pogo stick's spring when it is compressed and how much energy is gained against gravity when the spring is subsequently pushed back upwards. You will then find the percent energy converted from elastic to gravitational potential energy.

Your teacher will lead you through the details of the procedure. After listening to the explanation, remember to keep the following in mind:

- The rider cannot help to lift the pogo at all! Think 'deadweight'!
- The boppers need not push hard. In fact, if they push too hard, the pogo will 'bottom' out, producing a clicking noise. This will result in erroneous data because not just the pogo spring will be pushing the rider back up when the measurements are made.
- First and foremost, the boppers should think of themselves as spotters, responsible for the safety of the rider. This is particularly important on the final oscillation when the rider is being pushed upward by the spring alone.
- Measurers need to position their eyes low to the ground so that they can use the ruler to take accurate measurements. All heights are measured from the ground to the bottom of the collar. Measurers should stay several feet back from the pogo.

Data:

Collar Location	Trial #1	Trial #2	Trial #3	Average
Uncompressed Height (m)				
Low (m)				
High (m)				

x = change in spring length = uncompressed height – low = ___________ m

Δh = height gained after final compression = high - low = __________ m

Calculations:

1) Potential energy stored in the spring: $PEs = \frac{1}{2}kx^2$

2) Potential energy against gravity: $PEg = mg\Delta h$

3) % energy converted: PEg/PEs x 100%

D) <u>Questions</u>

1) When you calculated "% energy converted", why was the answer not 100%?

2) If a squeaky pogo stick were oiled, what would happen to your results?

3) Suppose your group had used a heavier person on the pogo stick when finding the spring constant in Section 1 of the procedure
.

a) What effect would this have on your calculation of the spring constant, 'k'?

b) What effect would this have on the calculation of change in spring length, ‘x’?

4) Describe the energy transformations that happen as a person hops freely on a pogo stick.

5) When this lab was originally designed, students jumped around freely on pogo sticks while others measured how high they jumped. They then calculated the % energy transferred and got results of up to 600%. How is that possible? Where did the extra energy come from?