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Potential vs. Kinetic Energy

Subject Area(s) measurement, number & operations, reasoning & proof, and science & technology

Associated Unit None

Associated Lesson None

Activity Title Is it Potential or Kinetic?

Header

Insert Image 1 here, right justified to wrap

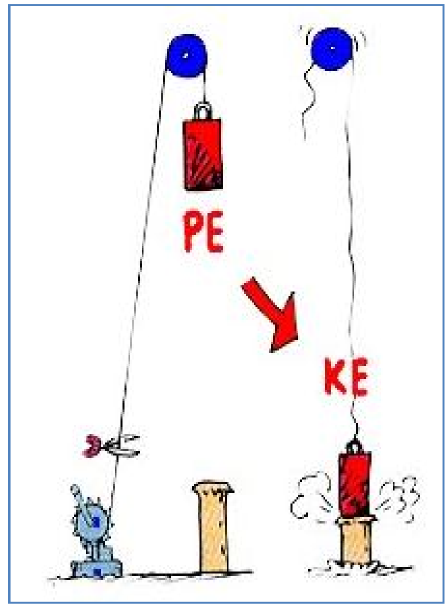

Image 1
ADA Description: temp
Caption: TEMP pic - need to insert students working on project
Image file name: Baseball-Bot2.jpg
Source/Rights: Copyright © Carole Chen 2010

Grade Level 6 (5-7)

Activity Dependency None

Time Required Two 45-minute lessons

Group Size: 4

Expendable Cost /Group US$4 (excluding price of Lego Mindstorm kit)

Summary

Working as a team, students learn about two energy forms, potential and kinetic energy, using the Lego Mindstorm kit. Potential energy is a form of stored energy that can be converted to kinetic once the object or system is set in motion. For example, when a roller coaster is at the top of the hill, the system has in within it potential energy. As the coaster's brake is let go, it will travel down the slope, all the while converting the stored potential energy to motion, known as kinetic energy. Equations can be used to relate the two forms of energy and this activity will explore the equations along with hands on Lego activity.

Engineering Connection

Energy is a very important topic and one that keeps our world going. Engineers need to be able to access all different sources of energy, especially renewable green energy. That is why it is essential that engineers and scientisits understand the concepts and relationships between kinetic and potential energy. It helps them design structures that utilizes waterfalls to create energy efficiently. For example, the Hoover Dam was built to harvest hydroelectricity. Gravitational force pulls water down the tall dam and as each water molecule's potential energy converts to kinetic energy, hydropower is generated. Hydroelectricity is the world's most used renewable source of energy. In fact, it is reponsible for producting 20% of the world's energy consumption.

Engineering Category (1) relates science concept to engineering/the use of technology

Keywords distance, gravitational force, height, mass, measure, motion, kinetic, potential, velocity,

Educational Standards

NYS Science: MST.4.I and MST.3.C [1]

Pre-Requisite Knowledge

Familiarity with measurement using a measuring tape, use of calculator, basic arithmetic and algebra skills (subtraction & division), experience with Lego Mindstorm kit, and the use of Mindstorms software

Learning Objectives

After this activity, students should be able to:

- Build and program a basic Lego NXT brick
- Calculate potential and kinetic energy based on given equations/relationships

Materials List

Each group needs:

- Lego Mindstorm kit (2 NXT bricks & 2 light sensors)
- Computer with NXT 2.0 programming, NXT 2.0 data logging, Microsoft Word and Excel
- Measuring tape/ruler
- Ramp (made of Lego pieces or any material that is available/convenient)
- Notepad and pen

Introduction / Motivation

Imagine yourself picking up a very heavy cardboard box filled with old books. Then hold it up with both arms lifted in front of you as high as you can. Every second you are keeping the heavy box up, your body is exerting energy to the box. The box now has "stored" energy called potential energy and it is held against the gravitational field. Now imagine your arms can no longer support the weight of the heavy box and give away, as the box drop, the "stored" potential energy is converted to kinetic energy.

The equations that relate potential and kinetic energies are as follows:

$$\text{Potential Energy} = \text{PE} = \boldsymbol{m} \times \boldsymbol{g} \times \boldsymbol{h} \qquad \text{Equation 1}$$

Where m represents mass of object, g represents gravitational acceleration 9.81 m/s^2, and h represents height (distance above a certain relative "bottom" or "ground").

$$\text{Kinetic Energy} = \text{KE} = \frac{1}{2} \times m \times v^2 \qquad \text{Equation 2}$$

Where again m represents mass of object and v represents velocity at which the object is traveling.

Let's use Image 2 below to help us further understand the important components of potential energy. In Image 2, on the left, we have two vehicles on the same leveled highway. The only difference is the mass of the two vehicles shown. The truck would obviously weigh more than the little car; hence we say that the truck is more massive than the car. An object that has more mass will have more potential energy as seen in Equation 1. On the right hand side of Image 2, we see that the same object (car) that is lifted at different heights will have different potential energy. For example, the car that is 10 meters high will have more potential energy than the car that is at 5 meters. *Please note that the height is relative. It should only be compared to each other if they are being measured using the same the relative beginning point.*

Insert Image 2 here, centered

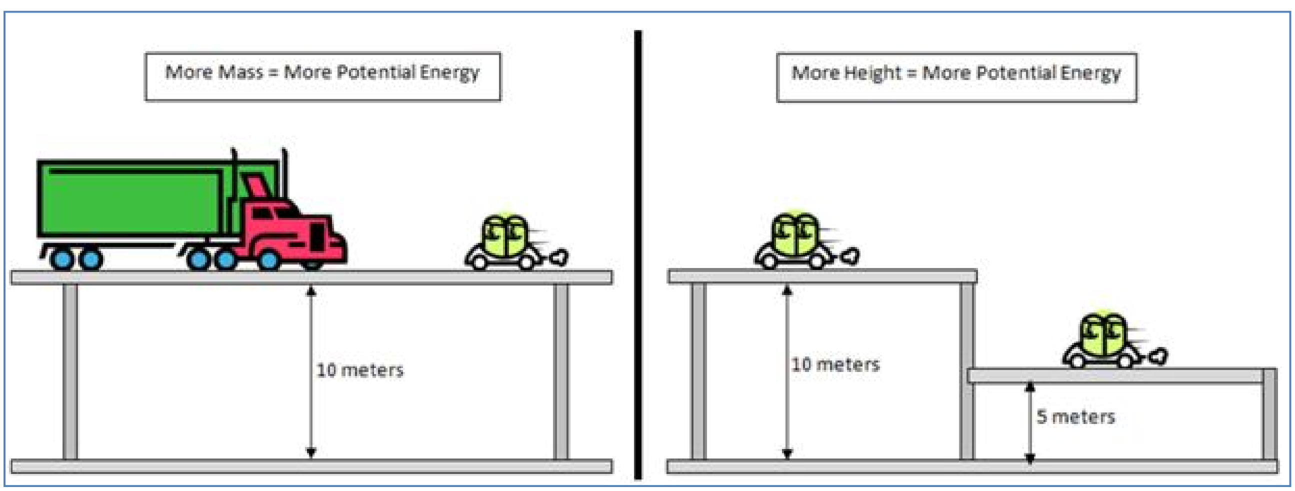

Image 2
Caption: Image 2: shows that height plays a major role in determining a system's potential energy
Image file name: PE_truck.jpg
Source/Rights: Copyright © Carole Chen 2010

As for kinetic energy, we focus our attention to Image 3, on the left we see that the truck and the car are moving at the same velocity. So velocity is not a variable here, instead the difference again here is the masses of the car and the truck. The truck is more massive, hence it will have more kinetic energy than the car. On the right hand side of Image 3, we have two cars of the same weight; however the difference here is the velocity. The car on the bottom is traveling faster (50 mph) compared to the car on the top (25 mph). So the car that is moving at a velocity of 50 mph will have higher kinetic energy.

Insert Image 3 here, centered

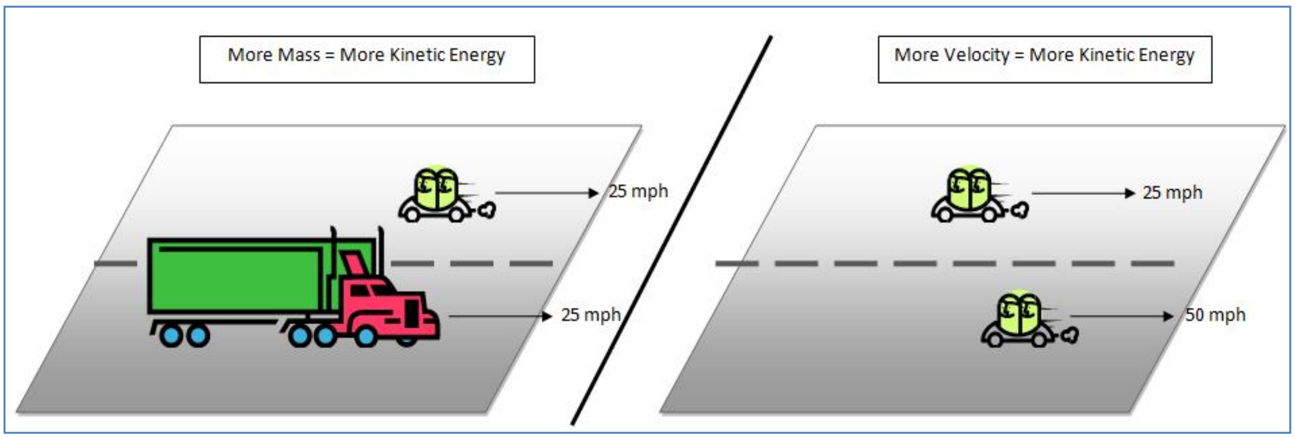

Image 3
Caption: Image 2: shows that speed (velocity) of an object in motion plays a major role in determining the kinetic energy of a system
Image file name: KE_truck.jpg
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Vocabulary / Definitions

Word	Definition
Height	the vertical dimension of extension; distance from the base of something to the top
Gravitational Acceleration	specific force or acceleration on an object caused by gravity. ...
Mass	the property of a body that causes it to have weight in a gravitational field
Velocity	rate of change in position with respect to time and direction of path; distance divided by time

Procedure

Before the Activity

- Gather all required materials
- Make sure all the Lego kits are complete with the parts properly divided

- Create large working space (may need to move desks to allow empty floor space if working in a classroom)
- Divide the class into groups of 4, (optional: assign roles to each person of the team – otherwise let the students choose)

With the Students

1. Discuss and go over the definitions of all the keywords making sure students understand what the terms represent.
2. Write on the board (in a sentence form) the relationships Equation 1 and Equation 2; ex: potential energy = mass of an object x gravitational acceleration x height at which the object is held.
3. Directly underneath the sentence relationships, write the equation relationships from Equation 1 and Equation 2.
4. Equate potential energy and kinetic energy; i.e. Equation 1 = Equation 2. This shows that all the potential energy can be converted to kinetic in an ideal situation. When we do this, we can calculate velocity (which is usually the unknown).
    a. $m \times g \times h = \frac{1}{2} m \times v^2$; solve for v^2
    b. $v^2 = 2 \times g \times h$
    c. $v = \sqrt{2 \times g \times h}$
5. Have students complete a brief <u>pre-activity experiment: *Is It Kinetic or Potential?* </u>(see attachment file)
6. After discussion of pre-activity experiment, each group can start the main activity. The main activity involves rolling an object, in this case a ball, down the tower of a ramp. When the ball is at the top of the ramp it has in its system potential energy which is measurable via Equation 1. Then once the ball is let go to roll down the ramp and onto the flat bottom part, it will have in its system all the converted potential energy as kinetic energy, and this is calculated via Equation 2 which has a velocity term in it. Hence we need to measure velocity using light sensors from the Lego Educational kit.
    a. Build a ramp to create height for ball to roll down.
    b. Refer to Figure 1.1 for an example of a ramp made of Lego (choice of material to make ramp is completely up to availability of classroom supplies). A good suggestion is to use something that gives variable height so that the experiment can be done at various heights.
    c. Refer to Figure 1.2 for an example of how the ball should be held in place at the top of the tower of the ramp. Extra Lego pieces can be added to the tower to create more height so that the ball can have more potential energy.

d. Once the ramp is built, connect two light sensors to a NXT brick (refer to Figure 1.1). One light sensor should be connected to Port 1 and the other should be connected to Port 4. This is done not because light sensors need to be in specific port, it is mainly for the purpose of avoiding entanglement of the cable wires.
e. The light sensors should be placed at least 12 inches apart from each other on the flat part of the ramp (as seen in Figure 1.1). This distance enables the two light sensors to captures the ball's passing motion without interference from one another. You might have to try several distances depending on the room's lighting condition.
f. Once the light sensors are connected, use the USB cable to connect the NXT brick to the computer.
g. Load the NXT 2.0 data logging software on the computer.
h. Refer to Figure 1.3 as an example of how the experimental setup should look like.
i. Now the whole experimental setup is ready for velocity data acquisition.
    i. Once NXT 2.0 data logging software is loaded and connected to light sensors NXT brick, click on "File" → "New". Refer to Figure 1.5 for experimental configuration.
    ii. When all required values are entered, click "OK". On the bottom right hand corner, there should be a control panel with a green arrow. Click this button when you are ready to start the experiment.
    iii. Once the program/experiment is loaded onto the light sensor NXT brick, you should hear a "beep" which signals that the experiment is running.
    iv. Let the experiment take a few seconds of data (this way you see two clear straight lines because the light sensors are detecting constant light values). *Make sure that no movement is made by anyone or anything which can be picked up by the light sensors (this would create confusion when you are determining peaks for which the ball crosses the two light sensors – you do not want to confuse surrounding movement with the ball's movement).
    v. Once a few seconds passed, immediately unblock the ball (from the figure, you would remove the white beam that is connected to a motor, which serves as the ball's blockage.
    vi. Refer to Figure 1.5 as example of how the experiment should look like on data logging. (Ignore remarks in bubbles).
    vii. Once the peaks are detected, use the point analysis tool to pinpoint the exact time the ball passes each sensor. Click on the tool and drag the yellow dotted vertical line to the beginning of the peaks. Refer to Figure 1.6 for the yellow dotted line.

Also refer to Figure 1.5 for the two points where the white arrows are pointing, these are the points you want to read off the x-axis time values.

viii. Jot down these values and the corresponding power level and light sensors distance on a notepad.

j. Now repeat the experiment at the same tower height three times to confirm the velocity.

k. Complete the activity worksheet, PE_KE_Activity_Worksheet.docx

Insert Figure 1.1 here, centered

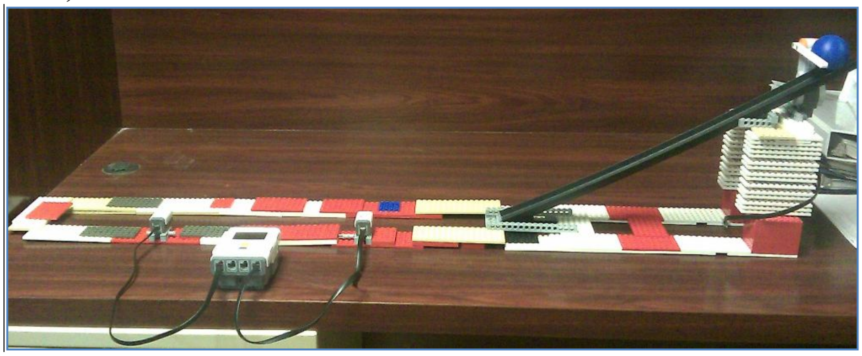

Figure 1.1
ADA Description: completed ramp
Caption: Figure 1.1: an example of a ramp needed for this activity. This particular ramp is made of LEGO any other material can be used.
Image file name: ramp1.jpg

Insert Figure 1.2 here, centered

Figure 1.2
ADA Description: tower to hold ball
Caption: Figure 1.2: ramp's tower holds ball in still max height position. The height of the tower can be adjusted by adding more LEGO pieces
Image file name: tower1.jpg
Source/Rights: Copyright © Carole Chen 2010

Insert Figure 1.3 here, justified

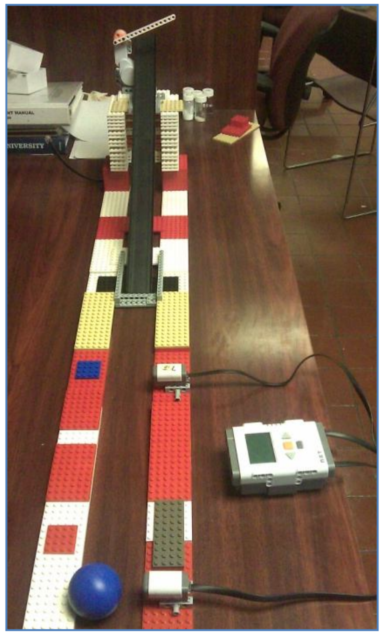

Figure 1.3
ADA Description: light sensors NXT
Caption: Figure 1.3: light sensors used to calculate velocity needed to determine kinetic energy of passing ball
Image file name: ramp2.jpg
Source/Rights: Copyright © Carole Chen 2010

Insert Figure 1.4 here, centered

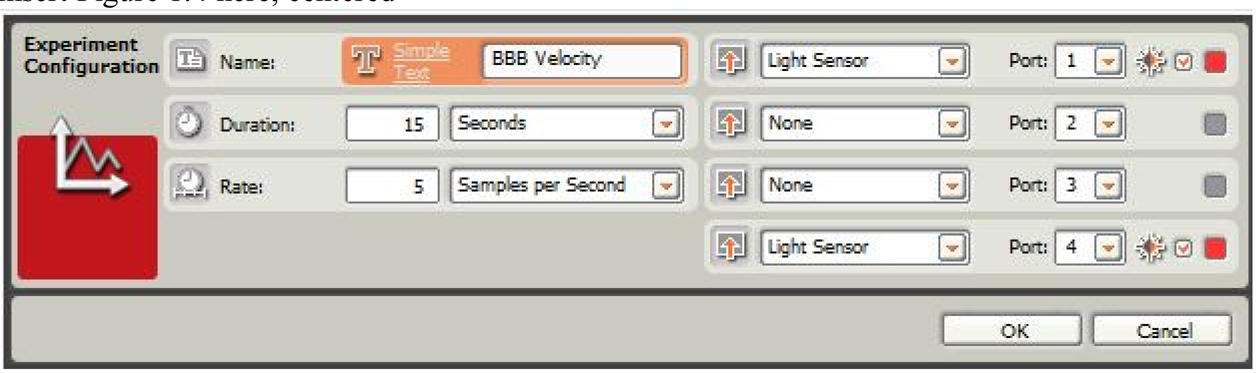

Figure 1.4
ADA Description: data logging software configurations
Caption: Figure1.5: use these figures for data logging software as an example, may adjust based on experiment's needs
Image file name: BBB Exp Config.jpg
Source/Rights: Copyright © Carole Chen 2010

Insert Figure 1.5 here, centered

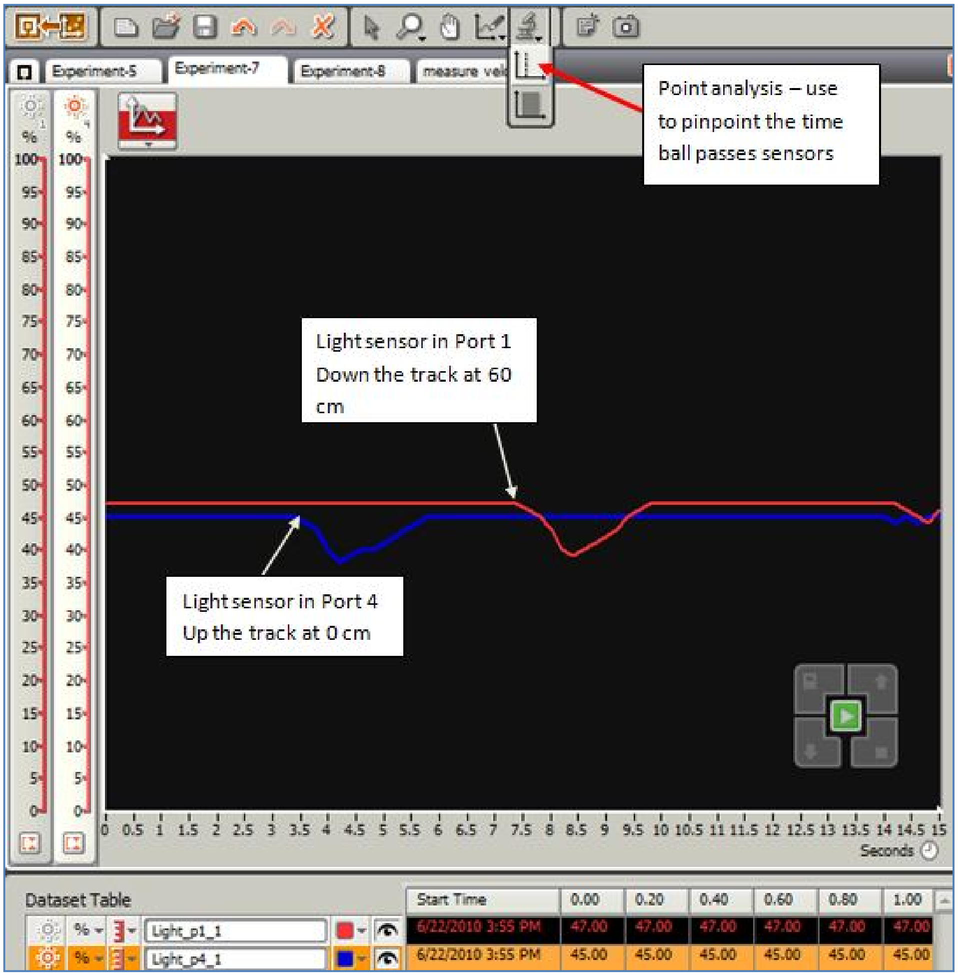

Figure 1.5
ADA Description: experimental data
Caption: Figure1.6: data collected using the configurations in Figure 1.5. Two peaks detected; one by light sensor in Port 4 (shown in blue) and another by light sensor in Port 1 (shown in red). Towards 15 seconds, noise was detected by hand movement to turn off program
Image file name: Data Logging1.jpg
Source/Rights: Copyright © Carole Chen 2010

Insert Figure 1.6 here, centered

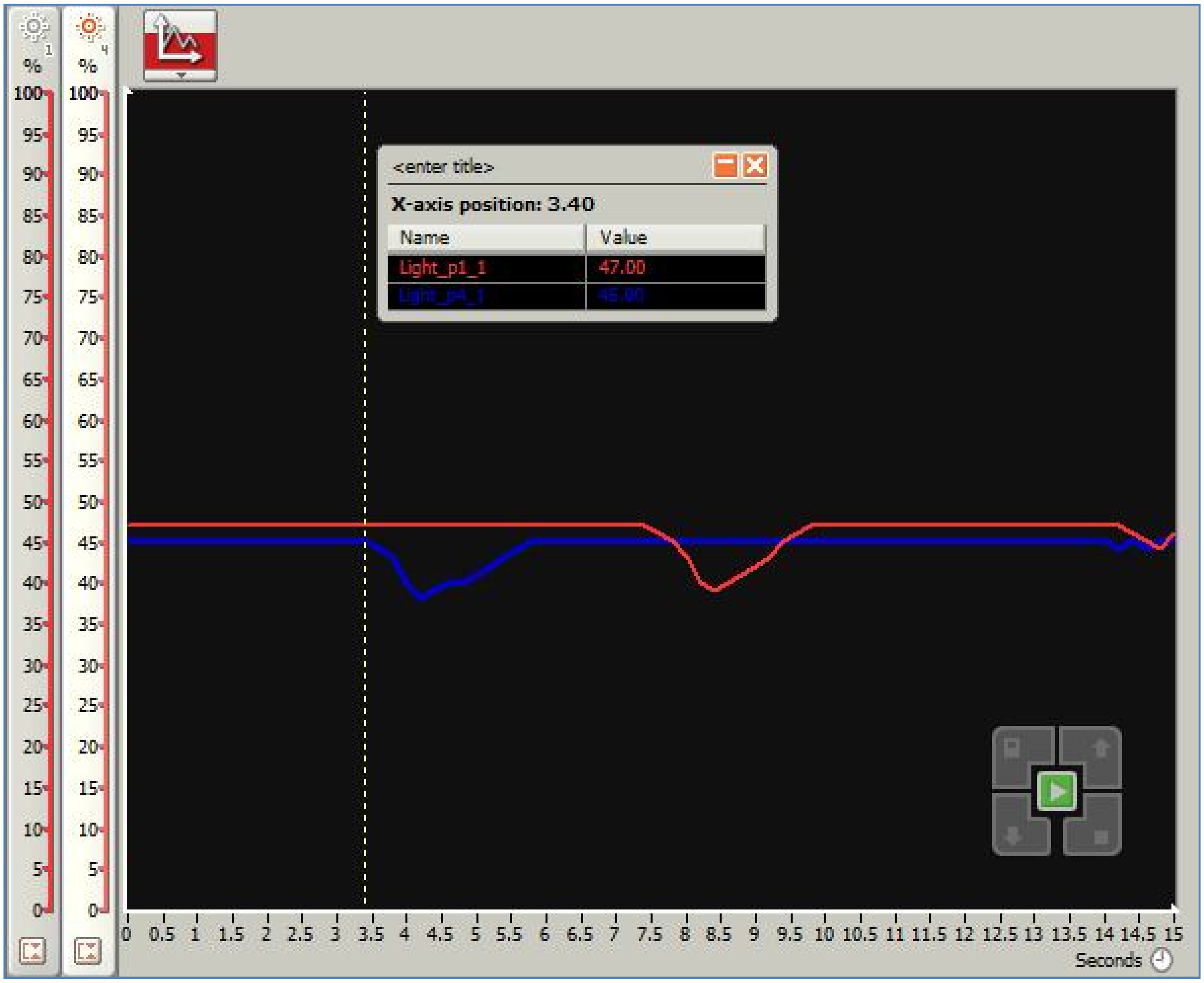

Figure 1.6
ADA Description: point analysis tool
Caption: Figure1.7: use point analysis tool to detect the time that light sensors picked up signal from ball moving across them. For example, shown in blue line, peak at 3.4 seconds is the time at which ball passes light sensor 4.
Image file name: Data Logging1.jpg
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Troubleshooting Tips

- Make sure there are no moving objects when the data logging experiment is being performed, otherwise a lot of noises will be detected and it is hard to determine which data spike is actually due to motion of the ball and not because of moving shadows.
- Keep the light sensors low to the ground; make sure the emitting light and receiving light bulbs are both at the level of the ball. If the light sensor is too high (that is not passing through the ball or just slightly skimming it), then the peaks (if any does appear) would be very small and can be easily confused with surrounding noises.

Assessment

Pre-Activity Assessment

Is it kinetic or potential?

Worksheet consists of basic questions that students should be able to answer after a lesson on kinetic and potential forms of energies. It uses an image of skiers at a ski slope to demonstrate various forms of energies.

Activity Embedded Assessment

Does the equality hold; kinetic energy = potential energy?

After students completed the activity, it is time for them to finally test out the validity of the equations. Theoretically, in an ideal situation, all the potential energy of a system should be converted 100% to kinetic energy. However, it should be concluded that it isn't always the case due to a simple fact of reality; friction. This concept should be explained to students well.

Post-Activity Assessment

Do different types of ramp surfaces affect the equality of the relationship; KE = PE ?

Repeat the experiment using different ramp surface. Try smoother surface which would give less friction and should see that the values for PE should be closer to calculated KE. Repeat this for various tower heights also. What are the effects of these changes, if any? Go over with students.

References

[1] www.nysed.gov

[2] en.wikipedia.org/wiki/velocity

[3] www.nxtprograms.com/baseball_batter/steps.html

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

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