

Parabolic Projectile Paths

Subject Area(s) mathematics, physics
Associated Unit None
Associated Lesson None
Activity Title Parabolic Projectile Paths

Header

Image 1

ADA Description: Students using experimental apparatus to measure projectile motion of a ball

Caption: Students using experimental apparatus to measure projectile motion of a ball

Image file name: student.jpg

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Grade Level 8 (7-9)
Activity Dependency None
Time Required 75 minutes
Group Size 28
Expendable Cost per Group US\$0

Summary Students use a ball launcher to study projectile motion. By using a LEGO NXT brick and light sensor to make a photogate and Mindstorms software with real-time data logging, students can measure the time of flight for a ball. Students use these data to estimate the maximum height attained by the ball by simultaneously solving three algebraic equations.

Engineering Connection Photogates are used by engineers to time events without having to use your own perception (like a stopwatch) or physically contact the object being timed (like the tape at the finish line of a race). These useful tools offer the students a chance to work with an accessible interpretation of a fundamental engineering device. In addition, the exploration of projectile motion lies at the heart of the basic physics that govern every branch of engineering.

Engineering Category (2) relates math concept to engineering

Keywords NXT Lego robot, parabola, projectile motion, systems of equations

Educational Standards

- State science:
 - Standard 4.5 (Physical Setting): Energy and matter interact through forces that result in changes in motion.

- State math:
 - Standard 1.3 (Scientific Inquiry): The observations made while testing proposed explanations, when analyzed using conventional and invented methods, provide new insights into phenomena.
 - Standard 3.1: Students use mathematical reasoning to analyze mathematical situations, make conjectures, gather evidence, and construct an argument.
 - Standard 3.5: Students use measurement in both metric and English measure to provide a major link between the abstractions of mathematics and the real world in order to describe and compare objects and data.
 - Standard 3.7: Students use patterns and functions to develop mathematical power, appreciate the true beauty of mathematics, and construct generalizations that describe patterns simply and efficiently.

Pre-Requisite Knowledge Basic functions and graphing, Cartesian plane, features of parabolas, second-order polynomials, simultaneous solution of systems of three equations with three unknowns

Learning Objectives

After this activity, students should be able to:

- Find the equation of a parabola from three points on the parabola
- Calculate the value of the parabola at its vertex
- Understand the relationship between a projectile flying through the air and a graph of its height over time
- Acquire data from the experimental apparatus using the LEGO NXT brick and Mindstorms software data logger

Materials List

Each group needs:

- Copy of worksheet (attached) for each student

To share with the entire class:

- Lego NXT kit (which can be purchased at <http://shop.lego.com/Product/?p=8547> for approximately US\$300)
- Computer with Mindstorms 2.0 (including data logging capability)
- Cardboard tube approximately 9 cm in diameter and 60 cm high
- Electrical tape
- Knife or scissors

Introduction / Motivation

Imagine throwing a baseball in the air and catching it in your hand. Now, think of a function describing the ball's height above your hand over time. How would it look? (It is a parabola opening downwards on the Cartesian plane, passing through the origin, and with vertex in the first quadrant.) The graph climbs up to a maximum as time increases, like the top of a hill, then descends back down. Where does it start? (If we say time starts when you throw the ball, it

“starts” at the origin.) What does the top of the hill mean? (It is where the ball reaches maximum height.) What speed is the ball moving at when it is at the top of the hill? (The ball has zero speed at maximum height.) In fact, the ball is slowing down from when it leaves your hand until it reaches the top and stops completely. Then it speeds up as it comes back down to your hand, but in the opposite direction as when it was climbing, that is, going down instead of up. Today, we are going to investigate this motion using a robotic sensor from the LEGO robotics kit.

Vocabulary / Definitions

Word	Definition
Gravity	The natural force of attraction exerted by a celestial body, such as Earth, upon objects at or near its surface, tending to draw them toward the center of the body
Projectile	Something which is thrown, fired, or propelled
Quadratic function	A polynomial with highest degree two, that is, having a “squared” term

Procedure

Background

Today, we are going to investigate this motion using a robotic sensor from the LEGO robotics kit. We will launch a ball with this little catapult up this cardboard tube. We use the light sensor to make a “photogate”, which is a beam of light that records when something passes through it. We put the photogate just above the ball when it’s on the ground. How many times will the ball pass through the photogate when it’s launched? (Two times, once going up and once going down.) Each time the ball passes through the light, it gets reflected back to the light sensor more strongly than when there is no ball and the light has to bounce off the back wall of the tube. So what do you think the light sensor will see over time after the ball is launched? (Two peaks with a little time in between them.) We are going to record the times the ball passes through the photogate and use these times to estimate the height the ball reached using algebra.

Before the Activity

- Build launcher in Fig.1 (see attached instructions)
- Make hole in cardboard tube
- Stick light sensor in, hold with duct tape
- Attach to port 4
- Program Mindstorms data logger and project onto a screen

With the Students

1. Introduce the students to the apparatus and the Mindstorms program in Figs. 2 and 3. Select one student to be the launcher, one to be the data logger, and one to be the analyst.
2. Have these three students practice the experiment a few times: The data logger should begin recording, see Fig 4, and the launcher should project the ball at exactly the two seconds mark.

3. When the students are ready, have them do an experimental trial. Once the data is captured, the analyst should determine by zooming in at what two times after the 2 second mark the reflected light measured by the light sensor spiked, see Figs. 5 and 6.
4. The data is collected for the class and written on the board. The students translate this data into three data points: the origin (0,0) as the two second mark when the ball was launched, and the two times when the reflected light spiked.
5. Ask the students how we can know the height at these times to make data points. The child with the correct answer (measure the height of the photogate) is given a ruler and can fill in the remaining two data points with the missing number.
6. Using these data, the students can complete the attached worksheet and questions.

Figure 1 [left justified]

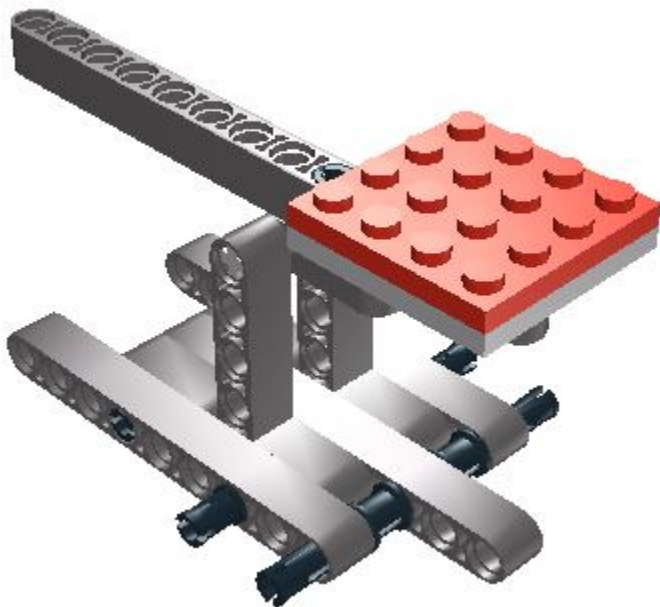


Figure 1

ADA Description: Schematic of LEGO ball launcher

Caption: Figure 1: Schematic of LEGO ball launcher

Image file name: fig1.jpg

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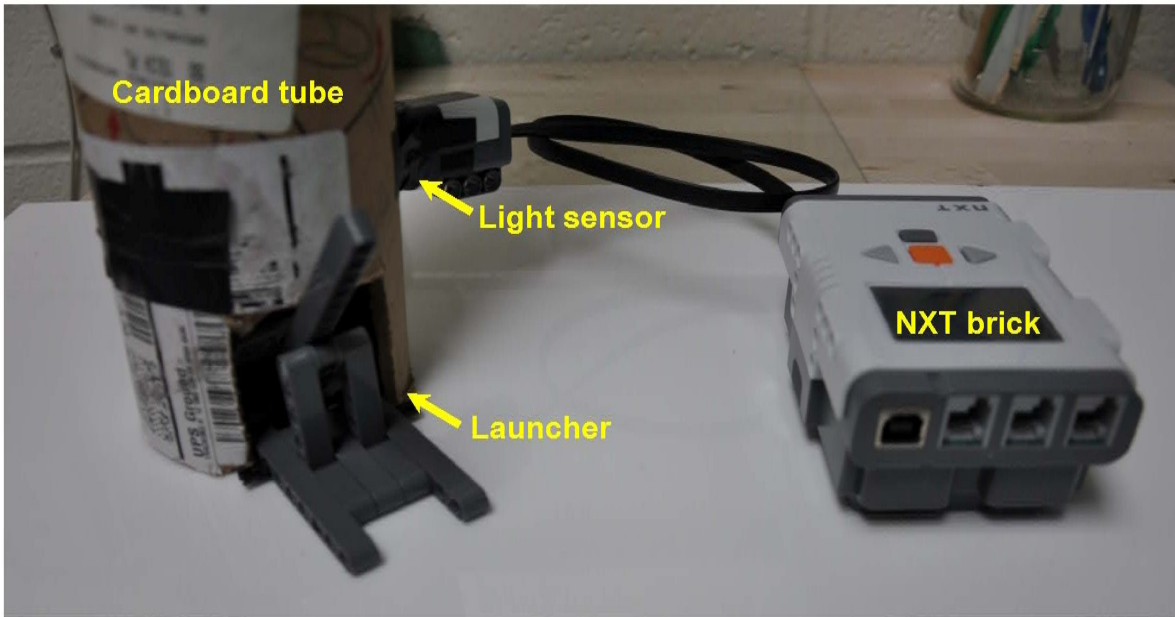


Figure 2

ADA Description: Close up of cardboard tube with light sensor attached, NXT brick, and ball launcher in place

Caption: Figure 2: Close up of cardboard tube with light sensor attached, NXT brick, and ball launcher in place

Image file name: fig2.jpg

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Figure 3 [left justified]



Figure 3

ADA Description: Complete experimental apparatus, including laptop with Mindstorms data logger

Caption: Figure 3: Complete experimental apparatus, including laptop with Mindstorms data logger

Image file name: fig3.jpg

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Figure 4 [left justified]

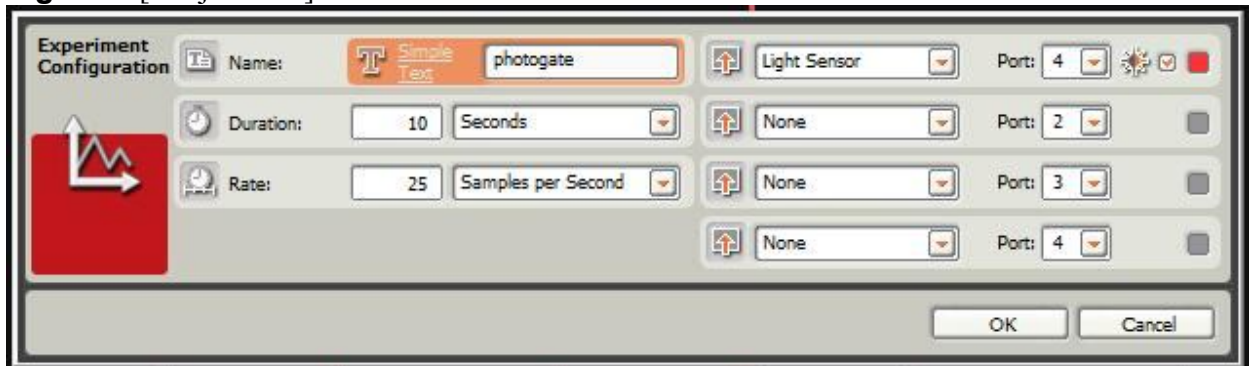


Figure 4

ADA Description: Screenshot of experiment settings in Mindstorms 2.0

Caption: Figure 4: Screenshot of experiment settings in Mindstorms 2.0

Image file name: fig4.jpg

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Figure 5 [left justified]

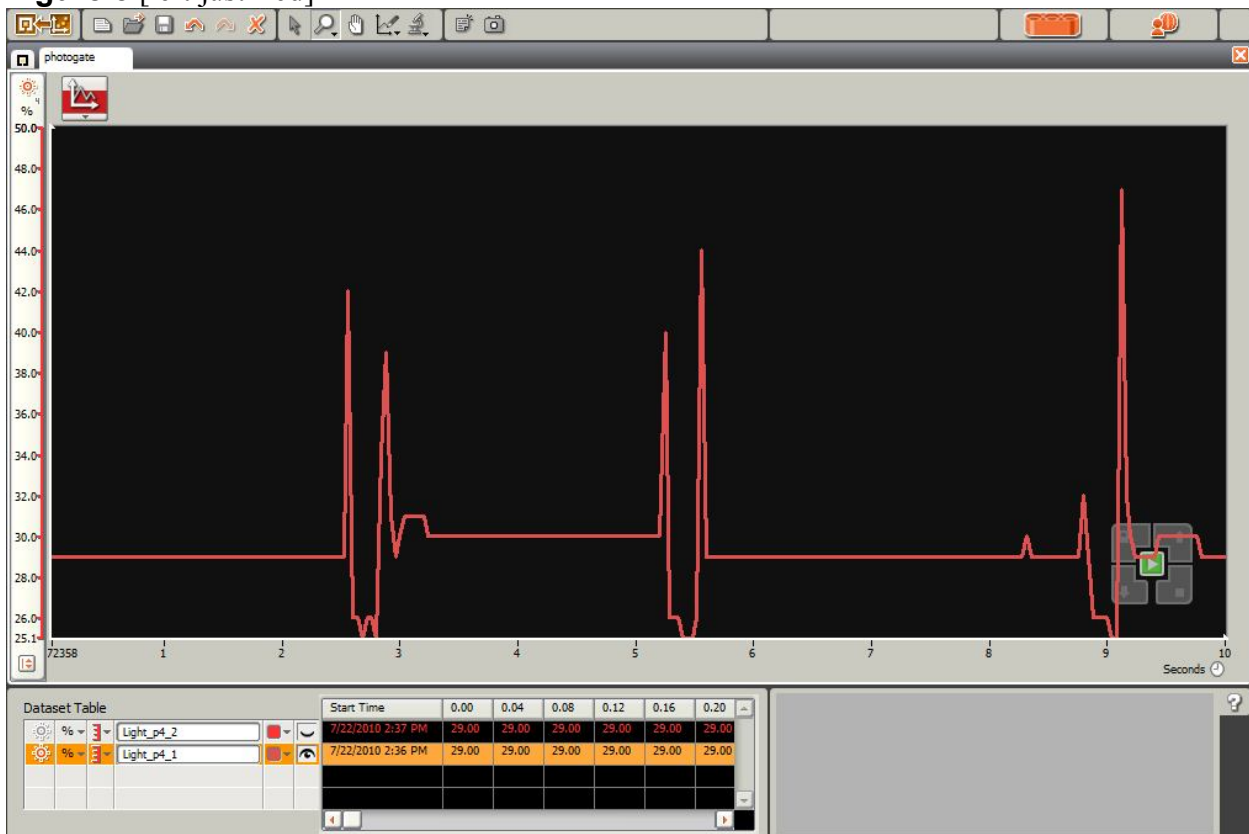


Figure 5

ADA Description: Screenshot of example experimental data from multiple ball launches

Caption: Figure 5: Screenshot of example experimental data from multiple ball launches

Image file name: fig5.jpg

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Figure 6 [left justified]

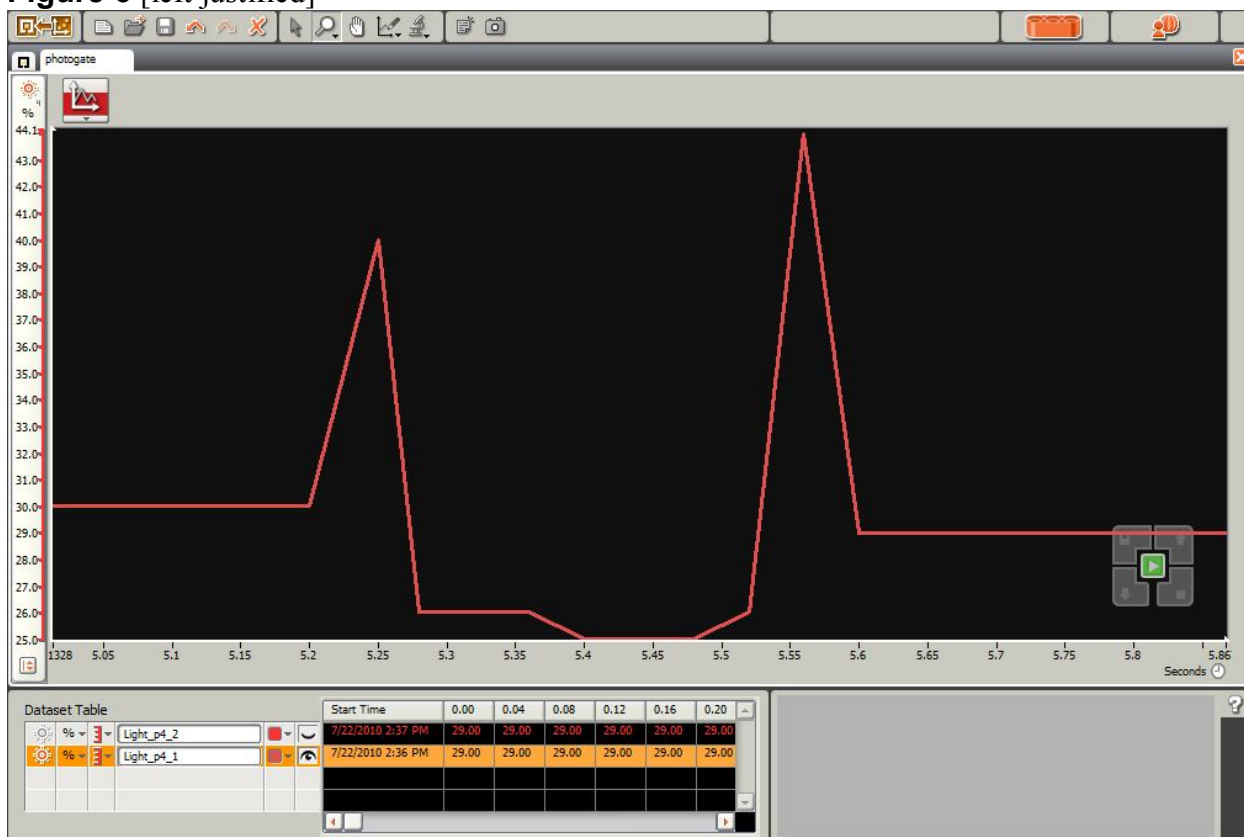


Figure 6

ADA Description: Screenshot of a close up of data from a single ball launch. Students would use this approximate closeness to acquire time interval of ball flight.

Caption: Figure 6: Close up of data from one launch

Image file name: fig6.jpg

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Attachments

Launcher building instructions (building_instructions.pdf)

Worksheet (PP_worksheet.doc)

Worksheet (PP_worksheet.pdf)

Worksheet with sample answers (PP_worksheet_answers.doc)

Safety Issues

- None

Troubleshooting Tips

Practice launching the ball before class to ensure that photogate gives two clear spikes in reflected light.

Investigating Questions

Why are there two spikes in the data? How could we orient the setup to get only one spike in the data? Would this be a practical setup with which we could complete the experiment?

Assessment

Pre-Activity Assessment

Title: How fast do things fall?

Ask students which falls faster in a vacuum, a bowling ball or a penny. The answer is that the acceleration of gravity is the same on both, so they fall at the same rate. Explain that when a feather falls slower than a bowling ball in air, this is due to air resistance. Note that when we usually do physics in middle school, we neglect air resistance, but today's project does not since it is based on experimental data in air.

Activity Embedded Assessment

Title: Experimental hypotheses

Have students explore the data mathematical using the worksheet. As they what shape they expect the data to describe before graphing.

Post-Activity Assessment

Title: Changing parameters

Ask the students how they expect the shape of the graph to change if a heavier ball is used. Why?

Activity Extensions None

Activity Scaling

- For lower grades, students can participate in the experiment, then fit the data to get a parabola instead of algebraically solving for the coefficients.
- For upper grades, the students can learn to use the LEGO NXT brick and create for themselves the program to use.

Additional Multimedia Support

References

Other

Redirect URL <http://gk12.poly.edu/amps-cbri/>

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