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The Ballistic Pendulum

AP Physics C – Mechanics

Learning Intention: I can calculate unknown quantities in a system by describing the energy and momentum in relation to time and calculating changes in energy and momentum as applicable.

Link to lab: https://ophysics.com/e3.html

Overview: The ballistic pendulum is one of the most common systems studied in mechanics because of the several physics concepts that it brings together. A bullet/marble is shot into a block that is suspended by rigid rods of negligible mass. The block and bullet/marble then travel together in a trajectory similar to a vertically hanging pendulum. Your goal is to determine the relationship between the initial velocity of the bullet and the height of the pendulum by plotting data in a graph and utilizing best fit curves. You will then verify the relationship through the theory!

Prelab

Before you start working with the variables, recording data, etc., take a minute to fire the marble into the block and watch the motion. Describe the physics that may be relevant in this problem, such as which laws you may need, why quantities are/are not conserved, or any other relevant physics that may assist in your answer. *Justify why you think the laws/conservation/physics are good choices, do not just say "the description says so."!* If you are unsure, check with Mr. Shah before moving on, once you have an answer for this section down.

Energy and conservation of momentum within a system are relevant to this problem. Momentum describes the relationship between two objects before and after collision, which can also help to find unknown final velocities after collision. Knowing the energy of the system before and after collision describes what type of collision occurs, whether it being elastic, inelastic, or explosion.

Procedure

Be specific about what you are doing. In particular, which quantities you are measuring, and which quantities you are holding constant and varying.

In our experiment, our independent variable is the initial velocity of the bullet, and our final velocity is the change of height after the bullet has been fired.

Data

Fill out at least 6 rows. More is better! Clearly state what values are in each column. You may add more columns if you need.

Table 1. *Note to students: Caption this table accordingly!*

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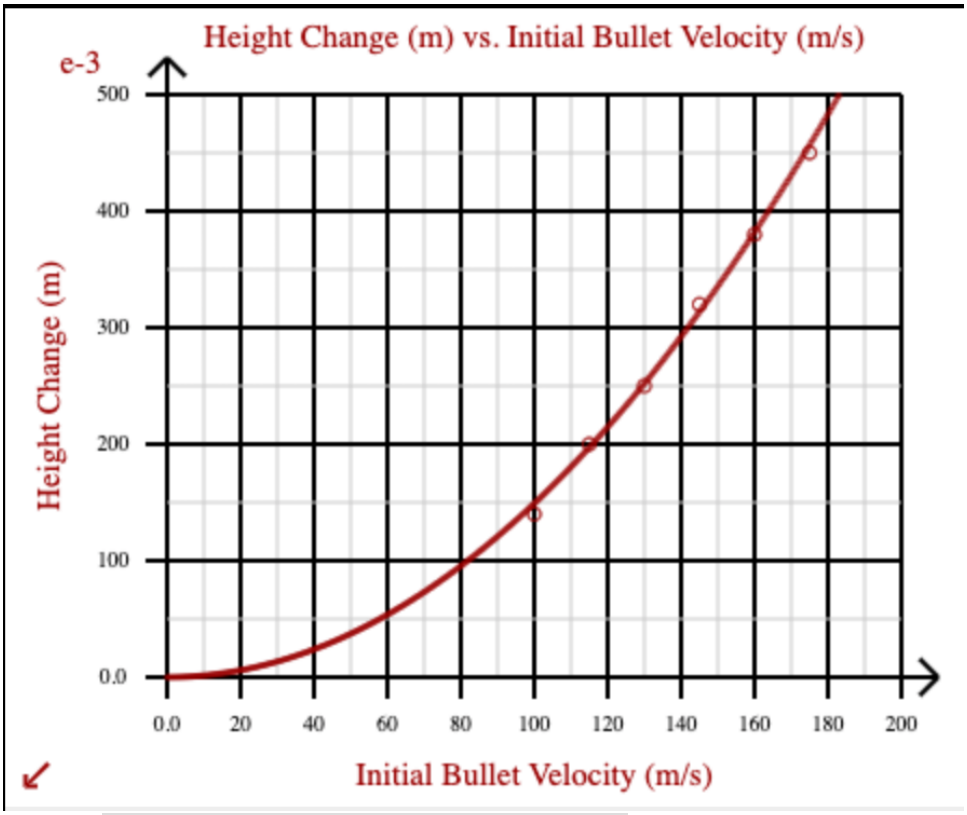
Initial Bullet Velocity (m/s)	Height Change (m)	Squared Initial Bullet Velocity ((m/s)^2)
100	0.14	10000
115	0.2	13225
130	0.25	16900
145	0.32	21025
160	0.38	25600
175	0.45	30625

Constants:
Mass of Block: 4 kg
Mass of Bullet: 0.075 kg

Results and Discussion

1. Choose quantities to graph for on the x- and y-axes of a graph. Include axes names with units as well as a graph title. Determine the best fit curve for the data using a power regression.



$$y = (1.491e - 5)x^2$$

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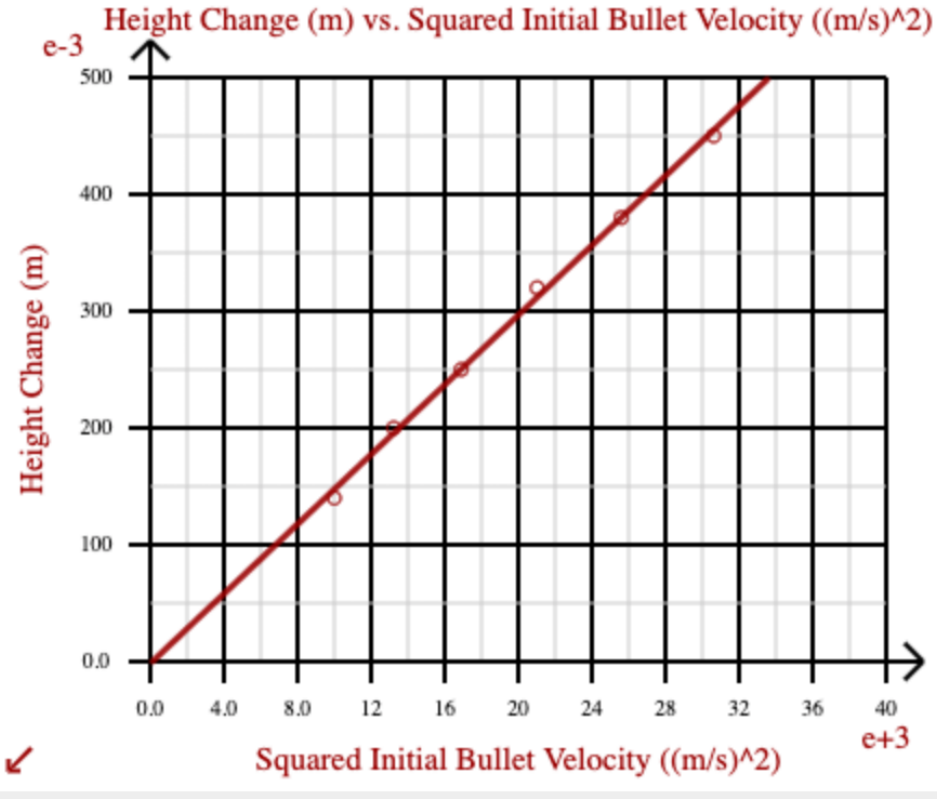
2. If the best fit curve is *not* a line (approximate power of 1), change the variables plotted so that you *do* get a line. Add any columns to your table above as needed to ensure that the data plotted is available in the table.



$$y = (1.491e-5) * x + (-1.711e-3)$$

Correlation: 0.99875

3. Summarize the results of your graph. How are velocity and height related?

As velocity of the bullet increases, the maximum height the block can go also increases.

4. Derive a theoretical expression for the initial velocity of the marble *u* using your answers from the Prelab.

   Vi=((mu+mB)vf-mB)/mu

5. Compare your expression with that from the graph. Are the results consistent? Analyze limiting cases for values in your expression from Step 4 to ensure that it makes physical sense.

The two expressions are consistent as they both represent a direct relationship between initial velocity and final velocity, with a greater velocity contributing to a greater change in height.

6. Derive an expression for the fraction of kinetic energy remaining in the system after the collision.

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K=½(mu)(vi)^2-mgh

Analysis Questions

Answer the following questions here:

1. You measure the height of a ballistic pendulum in the laboratory and obtain a value for the initial velocity of the marble using your expression that you found in the Results section. What is another way you could measure the initial velocity to check your answer? List equipment needed and steps to take (Hint: think simple! Don't overcomplicate this).

Kinematics could be used to find the initial velocity. A ball could be slid horizontally on a frictionless table for a measured amount of time until the marble is at rest. Through using 1D kinematics, the initial velocity of the marble can be found. The equipment used for this experiment would be a marble, a frictionless table, and a timer.

2. You find that the initial velocity obtained from your expression in the Results section is lower than what you measured using the extra equipment. List 2 reasons why this might be. Assume that instead of rigid rods holding the block, you used massless string.

The expected initial velocity might be lower than the actual because the actual experiment considers other variables such as friction and drag which can impact the initial velocity that the object would have. Additionally, the measured final velocity of the object might be different than the actual final velocity of the object, leading to a difference in the initial velocities as well.