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Projectile Motion Lab

AP Physics C – Mechanics

https://phet.colorado.edu/sims/html/projectile-motion/latest/projectile-motion_en.html

Objective: I will calculate kinematic quantities of an object in projectile motion given initial conditions of various launch speeds.

The required parts of the procedure are below:

1. Collect data. Leave air resistance off for today and hold *g* constant at 9.81 m/s/s.
2. Graph quantities according to what you collect. Make sure your graphs have units and axes labels. Also, ***caption any graphs you create like so, under the graphs: "*****Figure x.** Caption here.". Your captions should tell the reader what the graph is showing and for which system.
3. Linearize the graphs.
4. Explain what the slope and intercept mean, from your best fit line.
5. Conclude with "[vertical axis variable name] is related to [horizontal variable] and the expression relating the two is as follows: [expression here]."

Procedure

The values kept constant were mass, diameter, gravity, and launch angle. This is because mass and diameter do not have an effect on the motion, and gravity should remain constant in any projectile motion on Earth. The launch angle was kept constant for experimental ease.
The only value that varied was the initial launch speed, as that will be the variable in our final expression for the range of the projectile. The value we measured was the final horizontal distance at which the projectile landed on the ground.

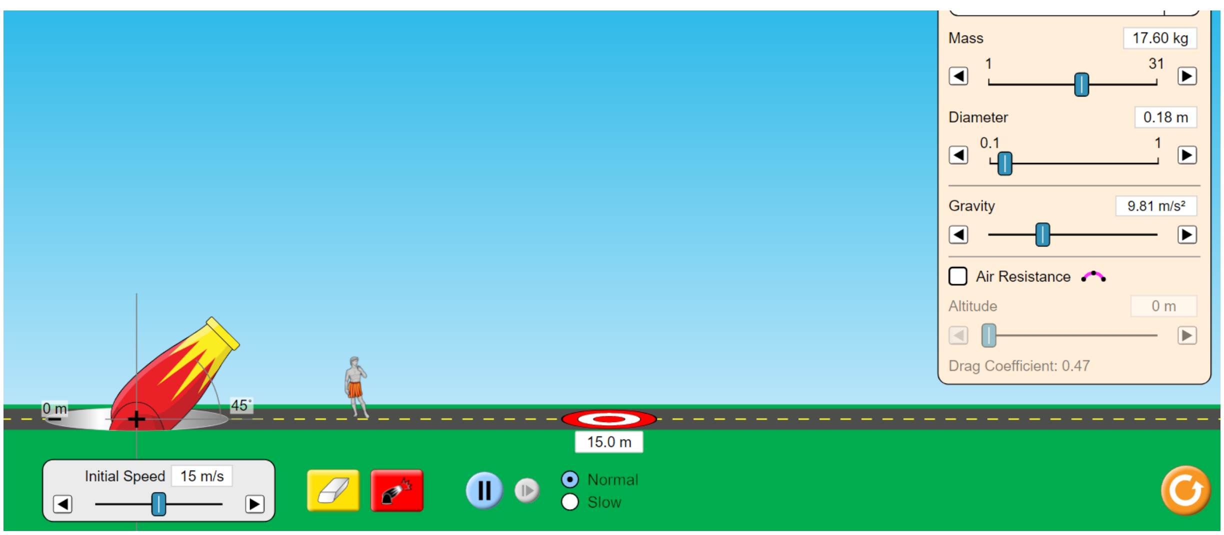

Figure 1. Sample image of setup with initial launch speed of 15 m/s

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Data

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7
Initial Launch Speed (m/s)	1	5	10	15	20	25	30
Square of Initial Launch Speed $\left(\frac{m}{s}\right)^2$	1	25	100	225	400	625	900
Launch Angle (degrees)	45°	45°	45°	45°	45°	45°	45°
Final Distance (m)	0.1	2.55	10.19	22.94	40.77	63.71	91.74

Results and Discussion

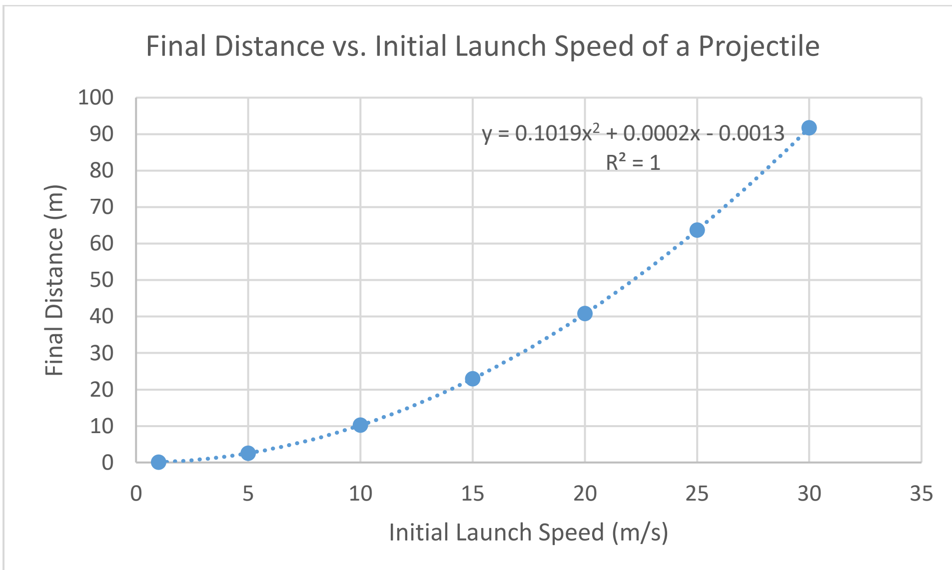

Figure 2. The graph of the original data for final distance as a function of initial launch speed, with is a quadratic relationship between the two variables.

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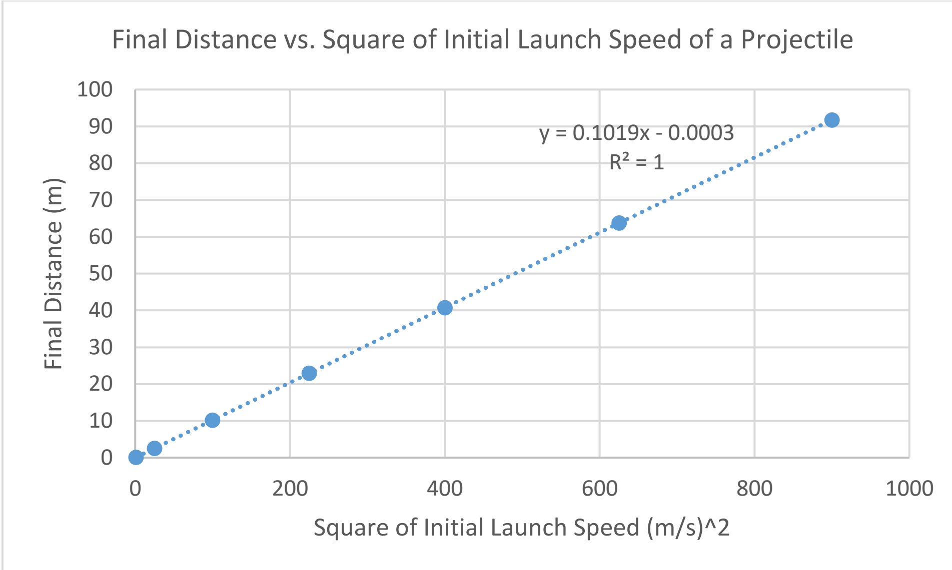

Figure 3. The graph of the linearized data representing final distance as a function of the square of initial launch speed.

The linearized graph has a y-intercept of approximately 0, meaning that the object will not move if the initial launch speed is 0. The slope of the linearized graph is 0.1019, which is equal to $\frac{\sin(2\theta)}{g}$, where θ is the launch angle and g is the gravitational acceleration on earth. This is the same as our slope from the derived equation of range (1), so our results are consistent with the theoretical slope of the range vs. square of initial speed.

Overall, the graphs reveal that final distance of the projectile is linearly related to the square of the initial launch speed, and the expression relating the two is as follows:

$$\Delta x = 0.1019 \cdot v_0^2 - 0.0003$$

Since the R^2 value of our trendline equation is 1, we confirm that our data is correct and consistent with theoretical values. Thus, our results make sense, and the theoretical equation is correct.

In the real world, we must account for air resistance on the projectile, which would cause the range to be less than predicted by the theory that considers air resistance to be negligible. We can minimize the air resistance by using objects that are minimally affected by it and more compact. Additionally, if the experiment was done in the real world, our data could be affected by wind traveling in either the direction of the projectile's general motion or against it, causing the range to increase or decrease, respectively. Another source of error could be angle and distance measurement inaccuracies, which can be fixed with more precise measurement tools. Some possible areas of future study could be to vary the initial height of the object when launched to compare the results with a derived equation for the optimal launch angle that maximizes range.

Post-Lab Questions

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1. Derive an expression for the range of an object using the constraints above. How does it compare to what you found using data?

$$0 = v_0 \sin(\theta) \cdot t - \frac{1}{2} g t^2$$

$$\frac{1}{2} g t^2 = v_0 \sin(\theta) \cdot t$$

$$t = \frac{2 v_0 \sin(\theta)}{g}$$

$$\Delta x = t \cdot v_x$$

$$\Delta x = \frac{2 v_0 \sin(\theta)}{g} \cdot v_0 \cos(\theta)$$

$$\Delta x = \frac{\sin(2\theta) \cdot v_0^2}{g} \qquad (1)$$

2. Derive an expression for the maximum height of the projectile from the ground. Your expression must be independent of time and should depend on initial speed v_0, launch angle θ, and physical constants as needed! How does it compare to the expression for the range? If you wish, support your expression with data. However, because it is a similar process to what you did for the range, I am not requiring you to collect data for this.

$$0 = v_y^2 - 2g\Delta y$$

$$v_y = v_0 \sin(\theta)$$

$$2g\Delta y = v_0^2 \cdot \sin^2(\theta)$$

$$\Delta y = \frac{v_0^2 \cdot \sin^2(\theta)}{2g} \qquad (2)$$

3. For an object that starts at a height above 0, is the angle needed for maximum range less than, equal to, or greater than 45 degrees? Justify your answer using words.

   For an object that starts at a height above 0, the angle needed for maximum range will always be less than 45 degrees. Since the object is already being launched from an elevated height, the time before the object hits the ground is greater as the ball needs to vertically be brought farther down. Thus, the vertical velocity can be made slightly less, as we do not need it as much to keep the ball in the air for a long since the elevation accounts for this, and the horizontal velocity should be made more to reach the max distance. To make this happen, the launch angle must be closer to the horizonal, meaning that it would be less than 45 degrees.