Juntang Wang

Projectile Targeting

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In this activity we want to explore a theoretical calculation and use it to make a prediction. There are two parts: you should complete part A and get a signature before starting on part B.

Part A: 10 points

Construct a ramp with the long aluminum rail, the black steel corner bracket, and some masking tape. The end of the ramp should be on the long arm of the bracket, and the bracket should be taped down so that it won't move. You must have the identical setup for part A and part B! If you roll the ball down from the top of the ramp, it should roll across the table for approximately 10 cm before falling onto the floor. You can tape some paper to the floor so that the ball lands on the paper. You should **always** have someone to stop the ball from rolling awy; you will not be given a replacement ball! Your task is to always release the ball from the rest from the top of the ramp, and then determine the horizontal velocity of the ball when it leaves the table. You are **not** allowed to use a timer or stopwatch. You are allowed to use a tape measure, and the fact that the acceleration of free fall is $g = 9.81\ \text{m/s}^2$. Some things that you might want to measure include: the length of the ramp, the height of the ramp where the ball is released, the length of the table that the ball rolls on, the height of the table above the floor, the horizontal distance between the edge of the table and where the ball lands.

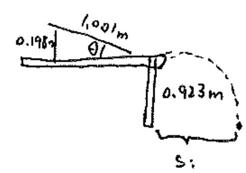
Determine what you want to measure, and construct a data table. Sketch a diagram that clearly shows what you are measuring. Make at least six measurements, and from you data, calculate the horizontal velocity v_x of the ball at the instant it leaves the table.

You will need to show at least one sample calculation that illustrates how you find v_x.

Table Height = 92.3 cm = 0.923 m = h

Track Height = 19.8 cm = 0.198 m

Track Lenght = 100.1 cm = 1.001 m



In Theoritical (no friction)

Two approachs: ① $v_{x1}^2 = 2ax$, where $x = 1.001\ m$.

$a = g\sin\theta = 9.81\ m/s^2 \times \frac{0.198}{1.001} = 1.94044\ m/s^2$.

$v_{x1} = \sqrt{1.94044\ m/s^2 \times 2 \times 1.001 m} \approx 1.97\ m/s$.

②.

Measurement	s_i (m)
1	0.571
2	0.570
3	0.568
4	0.571
5	0.570
6	0.570

$\bar{s} = \frac{1}{6}\sum_{i=1}^{6} s_i = 0.570\ m$

$s = v_x t$

$h = \frac{1}{2}gt^2$.

$v_{x2} = \frac{s}{t} = s\sqrt{\frac{g}{2h}} \approx 1.31\ m/s$

Instructor Initials:

As $v_{x2} << v_{x1}$, we infer it's not thooritical

i.e. fraction force matters here.

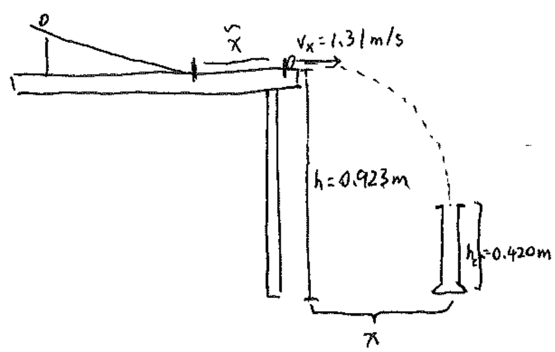
So we take $\boxed{v_x = v_{x2} = 1.31\ m/s}$

Part B: 10 points

After you have found v_x, ask for permission to measure the height of the target (a graduated cylinder). Using this measurement, calculate the location where you will place the target so that the ball, if rolled down from the top, will land exactly in the opening of the target, effectively catching the ball. Once you have determined where you will place the target, call the lab instructor, and they will let you place the cylinder. If you get it on the first try, your maximum score for this section will be 10 points, and you are done. If you require two tries, your maximum score for this section will be 8 points, and you are encouraged to check your part A result before doing a second try. If you require three tries, your maximum score for this section will be 5 points.

Below, you must show your calculations about where to place the cylinder, as well as a diagram that clearly shows what you measured and what variables you used to find the position.

$h_{cylinder} = h_c = 42.0\,cm = 0.420\,m$.



$x = v_x t$.

$y = h - h_c = \frac{1}{2} g t^2$.

$t^2 = \frac{2y}{g}$

$x = v_x \sqrt{\frac{2y}{g}} = \boxed{0.420\ m}$

How many tries before getting the ball in? If it is more than one, you must also clearly show where and how your computation changed above. Remember: No Erasing!

1 time.

Explain, in words, why trying to use a stopwatch to determine v_x would not be an effective method.

In my understanding using stop watch means measure time $\hat{t}$ the ball used to trave $\hat{x}$. then $v_x = \frac{\hat{x}}{\hat{t}}$. however, as $\hat{x} \approx 0.1\,m$ is relatively small, and the measurement of $\hat{t}$ can lack accuracy as it's ~~inter~~ Influenced by human reading and hard to catch the exact moment.

also, fraction forces matters. v_x can be smaller than $\hat{v}_x$

Instructor Initials: S.

PHYS 121 – Lab Report: Projectile Motion

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Date:	October 22, 2024
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Instructor:	Kai Wang and Chen Xi
Section:	Wednesday

1 Objective

The purpose of this lab is to analyze the motion of a projectile and verify theoretical predictions using experimental data. Specifically, we will investigate how the launch angle and initial velocity affect the horizontal range of a projectile, and compare our experimental results with the theoretical range formula derived from projectile motion equations.

2 Apparatus and Setup

Equipment Used:

- Aluminum rail (ramp)
- Black steel corner bracket
- Masking tape
- Steel ball
- Measuring tape
- Paper for marking landing points
- Graduated cylinder (target)
- Level table surface

Experimental Setup: A ramp was constructed using an aluminum rail and a black steel corner bracket, secured with masking tape. The ramp was positioned so that when a ball was released from the top, it would roll across the table for approximately 10 cm before falling to the floor. The table height was measured as 0.923 m, and the ramp height was 0.198 m. The track length was 1.001 m. The ball was always released from the top of the ramp, and the horizontal distance from the table edge to the landing point was measured to determine the horizontal velocity.

3 Data Table

Record your measured values in the table below:

Table 1: Experimental Data for Projectile Motion

Trial	**Launch Angle** (°)	**Initial Velocity** ($\mathrm{m\,s^{-1}}$)	**Horizontal Range** (m)
1	0	1.316	0.571
2	0	1.314	0.570
3	0	1.263	0.548
4	0	1.314	0.570
5	0	1.314	0.570
6	0	1.314	0.570

Key Measurements:

- Table height: $h = 0.923\,\mathrm{m}$
- Ramp height: 0.198 m
- Track length: 1.001 m
- Average horizontal distance: $\bar{x} = 0.570\,\mathrm{m}$
- Calculated horizontal velocity: $v_x = 1.31\,\mathrm{m\,s^{-1}}$

4 Data Analysis

Note on Range Formula: The standard projectile motion range formula $R = \frac{v_0^2 \sin(2\theta)}{g}$ does not apply in our experiment because our launch angle $\theta = 0°$. Since $\sin(2 \times 0°) = \sin(0°) = 0$, this formula would predict zero range, which is not useful for our horizontal launch experiment.

Determination of Horizontal Velocity for Each Trial:

The horizontal velocity v_x was determined for each trial using projectile motion equations. The ball falls from a height $h = 0.923\,\mathrm{m}$ and travels different horizontal distances.

Using the kinematic equations:

$$y = h - \frac{1}{2}gt^2 \tag{1}$$
$$x = v_x t \tag{2}$$

When the ball hits the floor, $y = 0$, so:

$$0 = h - \frac{1}{2}gt^2 \tag{3}$$
$$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2 \times 0.923}{9.81}} = 0.434\,\mathrm{s} \tag{4}$$

Therefore, for each trial: $v_x = \frac{x}{t} = \frac{x}{0.434}$

Individual Trial Calculations:

$$\text{Trial 1: } v_{x1} = \frac{0.571}{0.434} = 1.316\,\mathrm{m\,s^{-1}} \tag{5}$$
$$\text{Trial 2: } v_{x2} = \frac{0.570}{0.434} = 1.314\,\mathrm{m\,s^{-1}} \tag{6}$$
$$\text{Trial 3: } v_{x3} = \frac{0.548}{0.434} = 1.263\,\mathrm{m\,s^{-1}} \tag{7}$$
$$\text{Trial 4: } v_{x4} = \frac{0.570}{0.434} = 1.314\,\mathrm{m\,s^{-1}} \tag{8}$$
$$\text{Trial 5: } v_{x5} = \frac{0.570}{0.434} = 1.314\,\mathrm{m\,s^{-1}} \tag{9}$$
$$\text{Trial 6: } v_{x6} = \frac{0.570}{0.434} = 1.314\,\mathrm{m\,s^{-1}} \tag{10}$$

Average Horizontal Velocity:

$$\bar{v}_x = \frac{1.316 + 1.314 + 1.263 + 1.314 + 1.314 + 1.314}{6} = 1.31\,\mathrm{m\,s^{-1}} \tag{11}$$

Theoretical vs. Experimental Comparison:

The theoretical horizontal velocity was calculated using energy conservation:

$$v_{theoretical} = \sqrt{2gh_{ramp}} = \sqrt{2 \times 9.81 \times 0.198} = 1.97\,\mathrm{m\,s^{-1}} \tag{12}$$

The experimental value of $1.31\,\mathrm{m\,s^{-1}}$ is lower than the theoretical value due to friction and energy losses during the ball's motion along the ramp and table.

Target Placement Calculation:

For Part B, the target height was $h_{target} = 0.420\,\mathrm{m}$. The required horizontal distance to place the target was calculated as:

$$t_{fall} = \sqrt{\frac{2(h - h_{target})}{g}} = \sqrt{\frac{2(0.923 - 0.420)}{9.81}} = 0.320\,\mathrm{s} \tag{13}$$
$$x_{target} = v_x \times t_{fall} = 1.31 \times 0.320 = 0.420\,\mathrm{m} \tag{14}$$

5 Error Analysis

Several sources of uncertainty affected our experimental results:

Major Sources of Error:

1. **Friction and Energy Losses:** The ball experienced friction while rolling down the ramp and across the table, reducing its velocity from the theoretical value of $1.97\,\mathrm{m\,s^{-1}}$ to the measured $1.31\,\mathrm{m\,s^{-1}}$. This represents a 33% reduction in velocity.

2. **Measurement Uncertainty:** The horizontal distance measurements showed some variation (ranging from $0.548\,\mathrm{m}$ to $0.571\,\mathrm{m}$), indicating measurement uncertainty of approximately $\pm 0.012\,\mathrm{m}$.

3. **Surface Imperfections:** Small irregularities in the table surface and ramp could affect the ball's motion and introduce systematic errors.

4. **Release Point Consistency:** Slight variations in the exact release point from the top of the ramp could affect the initial conditions.

5. **Timing Method Limitations:** As noted in the lab, using a stopwatch would not be effective because the time intervals are too short (approximately $0.4\,\mathrm{s}$) and human reaction time would introduce significant errors.

Impact on Results: The experimental horizontal velocity of $1.31\,\mathrm{m\,s^{-1}}$ was significantly lower than the theoretical value of $1.97\,\mathrm{m\,s^{-1}}$, primarily due to friction. However, the target placement calculation was successful, demonstrating that the experimental method was valid despite the energy losses.

6 Conclusion

The experimental results demonstrate the practical application of projectile motion principles and highlight the importance of accounting for real-world factors:

- The horizontal velocity was successfully determined using kinematic equations, yielding $v_x = 1.31\,\mathrm{m\,s^{-1}}$

- The experimental velocity was 33% lower than the theoretical value due to friction and energy losses

- The target placement calculation was successful, demonstrating the validity of the experimental method

- The projectile motion equations accurately predicted the ball's trajectory despite energy losses

The experiment successfully demonstrated that while theoretical calculations provide a good starting point, real-world factors such as friction significantly affect the results. The successful target placement in Part B validates the experimental approach and shows that the measured horizontal velocity, despite being lower than theoretical, was accurate for practical applications.

The systematic difference between theoretical and experimental velocities (33% reduction) is primarily due to friction, which is an expected real-world factor. This experiment effectively illustrates the transition from ideal theoretical models to practical applications where energy losses must be considered.