**Experiment**

**7**

# Ballistic Pendulum

**Introduction**

The purpose of this experiment is to determine the muzzle velocity of a projectile launcher using two different experimental techniques.

Method 1

The muzzle velocity will be determined by measuring the horizontal distance and vertical distance of a projectile that is fired in the horizontal direction.

Method 2

The muzzle velocity of the projectile launcher will be determined using the ballistic pendulum, by applying the concepts of conservation of energy and momentum to the system.

## **Theory**

1. One can calculate the muzzle velocity of the projectile launcher from the measured range of the projectile and the distance traveled in the vertical direction. Using the equation governing the horizontal motion of a projectile fired in the horizontal direction, derive an expression for the initial velocity of the projectile in terms of the range of the projectile, Δx and its vertical distance, Δy. We’ll call this equation 1. Explain your equation.

1. Using the law of conservation of mechanical energy and the law of conservation of momentum, derive an expression for muzzle velocity of a projectile that is fired horizontally into a pendulum in terms of the mass of the projectile, m, and pendulum, M, the maximum angle reached by the pendulum, **θ**, and the length of the pendulum Rcm. Show this stepwise derivation in the space below. Indicate in words where you have applied the law of conservation of momentum and the law of conservation of mechanical energy. We’ll call this equation 2.

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### Procedure

**PART 1: Method 1**

1. Draw a line across the middle of a white piece of paper on the floor so the line is at the landing site (look for dents in floor). Then cover the paper with carbon paper.
2. Measure, ΔX0, the distance from launch position to end of base. Record your result in the Data section.
3. Put the steel ball into the Projectile Launcher and lock it to long range. Set =0o.
4. Shoot the ball, and record the horizontal distance, X, from the plumb bob to the landing spot of the ball in Table 1.
5. Repeat steps 2 and 3 four more times at the same angle above. Record range in Table 1.
6. Calculate the average range. Then record this value in Table 1.
7. Measure the vertical displacement of the center of the ball (the initial position of the ball is marked on the side of the barrel), YTotal. This is measured in two parts; ΔY0, vertical distance from launch position to top of table, and ΔY, vertical distance from top of table to floor.
8. Calculate the initial speed using equation 1 that you derived in the theory and record it in the data section of Part 1.

**Part 2: Method 2**

Diagram, engineering drawing

Description automatically generatedDiagram, schematic

Description automatically generated

1. Measure the mass of the ball, m, and the mass of the pendulum. Record them in the data section Part 2.
2. Clamp the pendulum base to the table. Place the pendulum in the base by screwing the pivot axle to allow the pendulum to hang freely. Make sure that the clamp does not interfere with the pendulum swing.
3. Measure the distance from the pivot point to the red dot in the pendulum (center of mass) and record it as Rcm in Table 2.
4. Latch the pendulum at 90° so it is out of the way, then load the projectile launcher to the ballistic pendulum mount at the level of the ball catcher.
5. Put the steel ball into the Projectile Launcher and lock it to the same range in Part 1. Move the angle indicator to zero degrees.
6. Fire the launcher horizontally and see how high the angle has reached.
7. Load the launcher, then set the angle indicator to an angle 1-2° less than that reached in step 5. This will nearly eliminate the drag on the pendulum caused by the indicator, since the pendulum will only move the indicator for the last few degrees.
8. Fire the launcher, and record the angle reached by the pendulum in Table 2. Repeat this measurement four more times, setting the angle indicator to a point 1-2° below the previous angle reached by the pendulum each time.
9. Calculate the average angle and initial speed of the ball (use equation 2). Record them in Table 2.

**Analysis**

**PART 1: Method 1**

1. Calculate the uncertainty in ΔX. Show all work.
2. Calculate the uncertainty in ΔXTotal. Show all work.
3. Calculate the uncertainty in ΔYTotal. Show all work.
4. Calculate the muzzle velocity of the ballistic pendulum using equation (1). Show all work.
5. Derive the expression for the uncertainty in the muzzle velocity of the ballistic pendulum that was obtained from equation (1). Then calculate its value. Show all work.

**PART 2: Method 2**

1. Calculate the uncertainty in θ. Show all work.
2. Calculate the muzzle velocity of the ballistic pendulum using equation (1). Show all work.
3. Derive the expression for the uncertainty in the muzzle velocity of the ballistic pendulum that was obtained from equation (2). Then calculate its value. Show all work.

**Data and Results**

**Part 1: Method 1**

ΔX0 (distance from launch position to end of base) = \_\_\_\_\_0.232m\_\_\_\_\_\_\_\_

#### **Table 1**

g=9.8006m/s2 (3 significant figures)

|  |  |
| --- | --- |
| Trial | Δx (m) |
| 1 | 2.452 |
| 2 | 2.372 |
| 3 | 2.362 |
| 4 | 2.362 |
| 5 | 2.342 |
| Average & Uncertainty | 2.38 |

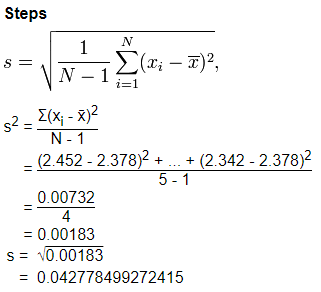
ΔXTotal =ΔX0 + ΔX = 0.238 + 2.146= **2.384m**

ΔY0 (vertical distance from launch position to top of table) = \_\_\_**0.925m**\_\_\_\_\_\_\_\_\_\_

ΔY (vertical distance from top of table to floor) = \_\_\_**0.075m**\_\_\_\_\_\_\_\_\_\_

ΔYTotal=ΔYo+ΔY = \_**1m**\_\_\_\_\_\_\_\_\_\_\_\_

Standard deviation and uncertainty for





Uncertainty of range ****ΔXTotal =. \_\_.07m\_\_\_\_\_\_\_\_\_\_

Uncertainty of range ****Δ YTotal = \_\_\_.07\_\_\_\_\_\_\_\_\_

Muzzle velocity v = \_\_\_\_\_5.28\_\_\_\_\_\_\_±\_\_\_\_0.2\_\_\_\_\_\_ (equation 1)

**Part 2: Method 2**

**Table 2**

|  |  |
| --- | --- |
| **Trial Number** | **Value (rads)** |
| θ1 | 38 |
| θ2 | 37 |
| θ3 | 38.5 |
| θ4 | 37 |
| θ5 | 37 |
| Average θ | 37.5 |
| m | 66.02 g |
| M | 236.3 |
| Rcm | 8 |

Muzzle velocity v = \_\_\_\_\_5.75\_\_\_\_\_\_\_±\_\_\_\_\_\_\_\_\_\_ (equation 2)

# Conclusion

Your conclusion must include a description of the experiment and its purpose, a discussion and statement of results, a discussion of random errors and systematic errors. In addition, discuss

* the purpose of the experiment.
* the procedure.
* whether or not the results agree with each other (don’t forget to include any evidence in your discussion).
* the dominant source of error.

The conclusion must be in paragraph form; otherwise, ten percent of the total points will be deducted.