Lab 4:
A Ballistic Projectile

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***Necessary Equipment*:**

1. Standard Ballistic Pendulum Apparatus & Ball(e.g., Cenco)
2. Standard Photogate & Digital Timer (e.g., Pasco)
3. Meter Stick
4. Masking Tape
5. 100 ml Nalgene Beaker and/or Medium-Size Paper & Wax-Coated Cup

***Ultimate Objectives*:**

1. To apply the principles underlying ***projectile motion*** so as to make a verifiable ***retrodiction.***
2. To probe the connection between ***Galileo's Principle of Relativity*** (esp. "Form 4") and the principles underlying ***projectile motion***.
3. To use the ***laws of physics*** in a vivid ***forensic investigation.***
4. To not get hurt.

***Immediate Objectives*:**

1. To determine where a "weapon" (ballistic pendulum) *must have been* located if a "bullet" (brass sphere) hit a particular target.
   → Specifically, to use analysis and computations (rather than trial and error) to determine where you must place your ballistic pendulum so that it successfully fires a brass sphere into a cup.
2. To not get hurt.

***What is known*:**

1. $\bar{V} \equiv \frac{d}{t}$
2. Under constant acceleration, $d = \frac{1}{2}at^2 + v_0 t$.
3. Axes are independent: movement in the y direction does not affect movement in the x direction (from Galileo's Principle of Relativity).
4. Gravity exerts a constant acceleration on all objects in free-fall, regardless of their initial velocity (discovered in lab 2).
5. This constant acceleration, abbreviated *g*, is approximately 9.8 m/s^2 (canonical).

***What is not known*:** Everything else.

***Procedures*:**

I. The Ballistic Pendulum.

A. Observe your ballistic pendulum. Yours is one model of a classic piece of equipment--ultimately intended as a means for determining the speed of a fired bullet. We will return to its classic use later on in the course--during our investigation of energy and linear momentum conservation. Right now, we are using it as, simply put, a gun. More specifically, we are using the ballistic pendulum as a means for insuring a reproducible and purely ***horizontal initial velocity***.

As you can see, this device has the potential to do real damage--both to inanimate and to animate objects. Therefore:

NEVER FIRE THE mechanism UNTIL YOUR LAB INSTRUCTOR HAS explicitly SAID TO DO SO.

You will be asked to perform a couple of test-shots in a few moments. First, just familiarize yourself with its configuration. Convince yourself that you understand how it works. Set it up for a test-shot.

B. Set up and aim your firing mechanism so that the brass sphere is destined to go as far away from other people as possible. **Look attentively around your table** and room to insure that all aiming separations are maximized.

C. When your instructor gives the word, with EXTREME CAUTION and SERIOUSNESS, perform a test shot. After you retrieve the brass sphere, your instructor may well ask you to do another one or two.

D. Once you have completed the test shots, fully hold your fire until further notice.

II. The Photogate.

A. The photogate, when connected to an appropriate output, provides the means for obtaining high-precision timings.

The photogate uses an infrared beam that is part of an electrical circuit. When you press the manual switch, a timer begins counting. When the beam is broken by a passing object, the circuit is broken and the timer stops. If you start your timer at the same moment that you fire an object, you will end up reading the total amount of time that elapsed while the object traveled from its firing point to the beam.

B. Familiarize yourself with the photogate until you can successfully time your brass sphere rolling (or being gently thrown) through the photogate. DO *NOT* USE THE FIRING MECHANISM FOR TESTING OUT THE PHOTOGATE.

III. The *Horizontal* Component.

A. Once you are familiar with the functioning of the photogate, you will use it to obtain the horizontal velocity imparted by the firing mechanism to the brass sphere.

Our working assumption is that the pendulum imparts a fairly reproducible velocity.

B. The photogate itself will produce a TIME. In order to determine a velocity, you will, of course, need a displacement.

Consider what displacement you need to measure in order to determine velocity. Consider why.

Hint1: The calipers will probably be more helpful than a meter stick in measuring the relevant displacement.

Hint2: For a variety of reasons, particularly GPR, you can assume that the ***horizontal velocity*** of the brass sphere is essentially a ***constant***: The initial, average and instantaneous at any point are all essentially the same.

Once you have decided what displacement to measure, answer the following questions as preparation for your formal report:

In 1 - 3 complete sentences of English, explain <u>what</u> you measured for a displacement and <u>why</u> this measurement is relevant for a calculation of the sphere's velocity through the photogate.

*** Let x stand for Horizontal Displacement. In centimeters, enter your displacement: x = _____ cm.

C. Arrange your pendulum and photogate so that you can time the sphere through the gate -- ***shortly after it emerges from the firing mechanism***.

DO NOT FIRE through the photogate UNTIL you get permission from your instructor.

D. Once you have permission, repeatedly fire the brass sphere through the photogate until you obtain 3 - 5 timings. Record these timing in the table below.

for each timing, **do everything possible to <u>*prevent*</u> the sphere from hitting the ground.** such prevention is important both for safety and for scientific investigation.

Trial	Horiz. Displacement [cm] (Constant Through All Trials)	Time [s]	Horizontal Velocity [cm/s]
1			
2			
3			
4			
5			

IV. The *Vertical* Component.

A. Using your meter stick, measure the height from which your sphere will be fired from the ballistic pendulum: in other words, measure the **vertical displacement** that the bullet will have in the course of its trip. Use the variable y for vertical displacement. y = _____

B. Determine how much ***time*** [sec] an object dropped from rest would take to free-fall the vertical displacement you obtained above.

V. Synthesis.

A. If you think about it hard enough, you will see that you now have all the information you need in order to make a ***retrodiction***.

B. Place your target (cup) at some appropriate and reasonable location on the floor. Using masking tape, secure the target.

C. This target represents something or someone that, if you do everything correctly, will have gotten shot.

D. Assume that the weapon had been at the height you measured. Do whatever calculations you need to determine:

At what (horizontal) range from the target was the weapon?

E. Using JUST YOUR METER STICK (NO TRIAL/ERROR):

Place your firing mechanism at the location you determined.

When and only when your instructor permits:
Re-Enact the Crime: Fire Away!

If you are a (physics) law-abiding citizen, your sphere should land in the cup!