

PHYS 2401 LAB Ballistic Pendulum

Purpose: In today's lab you will be determining the muzzle velocity of the projectile launcher by launching a ball to the pendulum.

Materials: ballistic pendulum apparatus, steel ball, stopwatch, mass balance, string, ruler, photogate

Theory: The muzzle velocity of the projectile launcher is determined by launching the ball into the pendulum and observing the angle to which the pendulum swings. The launch velocity of the ball is given by the following equation (refer to the additional handout provided to you for the derivation)

$$v = \frac{1}{mR_b} \sqrt{2IMgR_{cm} (1 - \cos \theta)} \quad \text{Equation 1}$$

where M is the mass of the pendulum and ball combined, m is the mass of the ball, g is the acceleration due to gravity, R_{cm} is the distance from the pivot to the center of mass of the pendulum, R_b is the distance from the pivot to the center of the ball, θ is the angle reached by the pendulum, and I is the moment of inertia of the pendulum with the ball in the catcher.

The value of I can be found by measuring the period of small oscillations of the pendulum and ball and using the equation (refer to the additional handout provided for the derivation)

$$I = \frac{T^2}{4\pi^2} MgR_{cm} \quad \text{Equation 2}$$

Preliminaries:

- Attach the projectile launcher to the ballistic pendulum mount at the level of the ball catcher. Make sure that the pendulum can hang vertically without touching the launcher.
- Clamp the pendulum base to the table. Make sure that the clamp does not interfere with the pendulum swing.



Procedure:

1. Latch the pendulum at 90° so it is out of the way, then load the projectile launcher (use long range). Allow the pendulum to hang freely, and move the angle indicator to zero degrees.

2. Try firing the metal ball to the catcher so the pendulum swings to an angle between 20° and 40° . Add or remove mass from the bottom of the pendulum to have a lower or higher angle.

3. Load the launcher, then set the angle indicator to an angle $1-2^\circ$ less than that reached in step 2. We do this adjustment so as to eliminate the drag on the pendulum caused by the indicator, since the pendulum will only move the indicator for the last few degrees.

4. Download the workbook for the lab. Fire the launcher, and record the angle reached by the pendulum in Table 1. Repeat this several times, setting the angle indicator to a point $1-2^\circ$ below the previous angle reached by the pendulum each time.

5. Remove the pendulum from the base by unscrewing and removing the pivot axle. Using the digital balance, find the mass of the pendulum and ball together (M) and the mass of the ball (m). Record these values in the Table 2.

6. Tie a loop in the string, and hang the pendulum from the loop. (See Figure 9.2) With the ball latched in position in the ball catcher, adjust the position of the pendulum in this loop until it balances. You may find it easier to do this by balancing the pendulum on the edge of a ruler. Measure the distance from the pivot point to this balance point, and record it as R_{cm} .

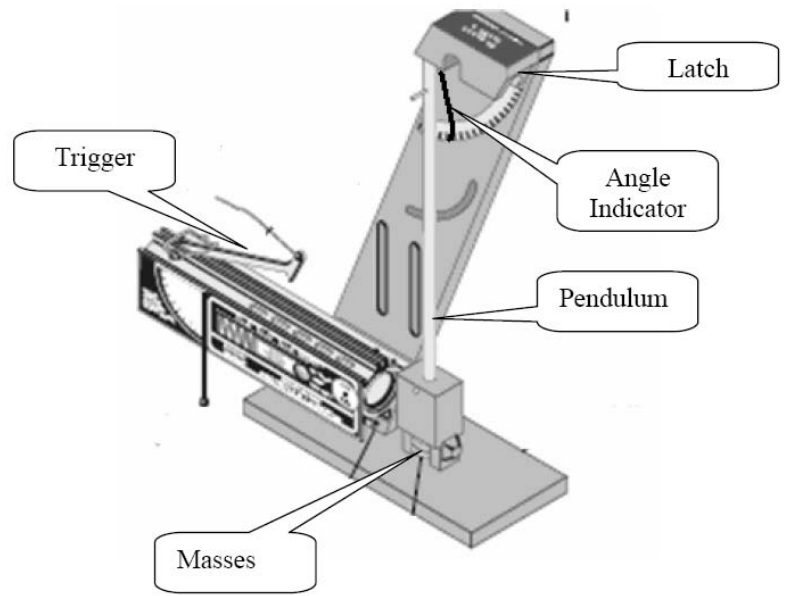


Figure 9.1. The Ballistic Pendulum Apparatus

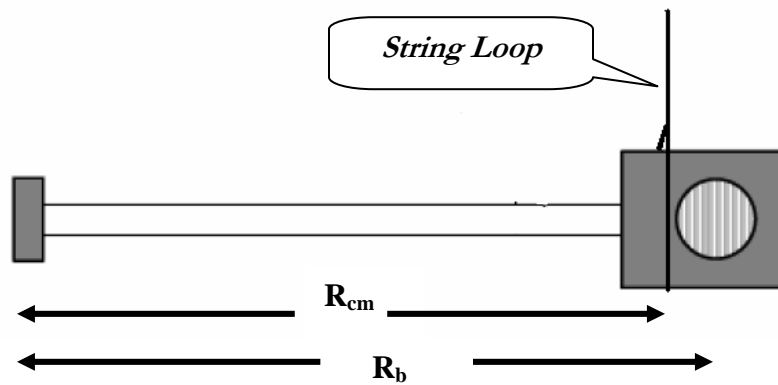
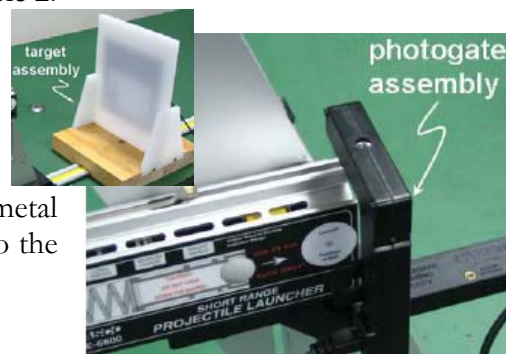


Figure 9.2 Balancing the Pendulum

7. Measure the distance between the pivot point and the center of the ball. Record this as R_b .
8. Replace the pendulum in the base, making sure that it is facing the right way. Be sure that the angle indicator is to the right of the pendulum rod.
9. Remove the launcher so that the pendulum can swing freely. With the ball in the pendulum, give it an initial displacement of 5° or less. Using the stopwatch, time how long it takes to go through at least ten oscillations. Divide this time by the number of oscillations, and record your result as T in Table 2.
10. Using Excel, calculate the value of I using equation 2, and then calculate the muzzle velocity of the projectile launcher using equation 1. Record the values in Table 2.

11. Measure the velocity of the ball using the photogate. Mount the photogate as shown in the figure at right. On the set-up menu choose "Velocity in Gate" for the quantity to be measured. Click the Constant tab and set the flag length to be the diameter of the ball. Use the target assembly to stop the metal ball. (Note that you don't need to connect the target assembly to the PASCO interface).



12. Complete Tables 3 and 4.



How do the two values of the velocity of the ball compare? Justify your answer.



An approximate equation for velocity is given by
 What is the value of velocity when you use this equation? Is there a significant difference between this value and the value you got using equation 1? What factors would increase the difference between these two results? How would you build a ballistic pendulum so that the approximate equation gave better results?

$$v = \frac{M}{m} \sqrt{2gR_{cm}(1 - \cos \theta)}$$