LAB 7: The Ballistic Pendulum*

Equipment List:

ballistic pendulum assembly
contact paper
stopwatch
pan balance
blank sheet of paper
tape
meter and two meter sticks (as needed)
spirit level
ruler

Purpose: To understand the ballistic pendulum and how the using the conservation of energy and momentum can allow you to find the initial speed of a projectile.

Introduction: In this experiment you will calculate the range of a projectile that is launched horizontally by a ballistic pendulum by applying the conservation of momentum in the collision and energy in the pendulum swing.

Theory: In your lab book, clearly derive an expression for v_b the launch speed of the ball, in terms of the height the center of mass of the pendulum rises, h, the acceleration due to gravity g, the mass of the ball, m_b, and the mass of the pendulum, m_p.

Using the projectile motion equations, find an expression for the range R of a projectile, launched horizontally from a height d with a speed v_b.

Put these expressions together to obtain an expression for R in terms of h, m_b, d and m_p.

Procedure:

1. Set up the ballistic pendulum system. Level the platform with the spirit level as a reference by adjusting the screws underneath.

2. Push back the spring-loaded tube that will launch the ball. Put the ball into the pendulum catcher. Set the pendulum swinging with from a small angle, about 5° or so and use the stopwatch to time ten full oscillations. (Count carefully!) Make sure that the ball catcher is swinging freely and not striking the gun rod. Make a note in your lab book of what the time on the stopwatch is, and then divide by 10 and note that down as the period, T. You will use this in a later week.

*Based on the labs by Prof. Luna and Prof. Newton.

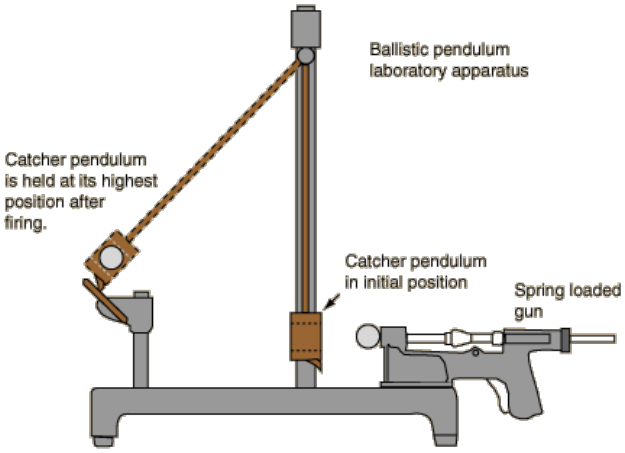

Figure 1: Ballistic Pendulum apparatus sketch. Figure from Hyperphysics website, GSU.

3. Locate the center of mass of the ball-and-pendulum system. It should be marked on the pendulum. Tape the sheet of paper to the vertical support of the pendulum and mark with a pencil the height of the center of mass. Pull the pendulum up out of the way so that it sits on the catcher ratchet. Use the ruler and spirit level (to make sure the ruler is level) to draw a horizontal line on the paper from the marked center of mass dot over to the side where the pendulum will be caught by the catcher ratchet.

4. Measure the mass of the ball, m_b, with the pan balance. The mass of the pendulum m_p is marked on the pendulum.

5. Prepare the gun for firing by pushing back the spring-loaded tube and placing ball on gun rod.

6. Place the pendulum at rest in its vertical position. Make sure there is a rubber band around the pendulum prongs on the opposite side from the gun.

7. Check that your hands and your partners hands are out of the line of the pendulum. Pull the gun trigger. The pendulum should be caught at the maximum height of its swing. Mark the center of mass height on the paper with a pencil.

8. Measure the height, h. This is the vertical displacement of the center of mass of the ball and pendulum system. If you have marked the line on the paper, you should just be able to measure the vertical distance from your line to you new point.

9. Repeat firing the gun and measuring the height to give a total of 5 repetitions.

10. Calculate the average value of h. Come to the front and measure the height of the bench at the front and add that to the height of the ball when it is on the gun rod on your launcher. This total height is d. (See Figure 2.) Use the average value of h and d to calculate R. Take this to be the predicted value R_{pred}.

11. Get a piece of contact paper. Mark the center of it.

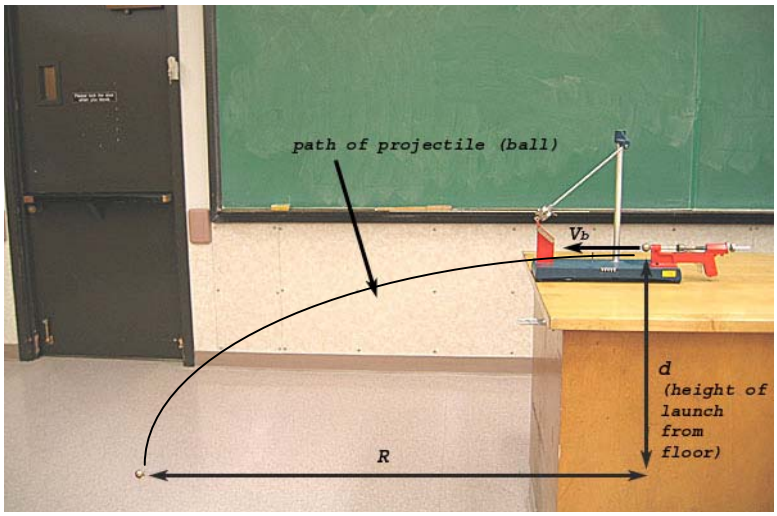

Figure 2: Path of the projectile.

12. Bring your ballistic pendulum assembly to the front lab bench and measure out the distance R_{pred} from the point where the ball is launched. Center your contact paper on the floor at the point the ball is supposed to strike.

13. With the pendulum out of the way, prepare the gun for firing. Make sure that the line of fire is clear. Do not fire if anyone could be hit. Call me over to witness the shot and whether the ball strikes the target or not. If you miss the paper altogether, go back and check your calculations before trying again.

14. Once you hit the target, fire five times in total and find the average distance, $\bar{R}_{\text{meas}}$.

Conclusion:

Using the error propagation formula, derive the specific formula for the uncertainty, δR for R. If you plug your values into it, you will get a very small number for the uncertainty. (Go ahead and do it if you like.) However, you might find that your value for $\bar{R}_{\text{meas}}$ is not precisely equal to R_{pred}. Why do you think in this case δR might underestimate the actually error in this experiment?

Find the percentage difference between the values $\bar{R}_{\text{meas}}$ and R_{pred}.

What errors are there in this experiment? Are they systematic or random? What effect do you think the mass distribution of the pendulum has on the results?