Ballistic Pendulum

Goal: Apply conservation principles to the motion of a ballistic pendulum to determine the velocity of a projectile, and to predict the range of that projectile when launched horizontally from a tabletop.

Lab Preparation

There are three main concepts applied in this lab and you should review each of them.

Projectile motion - Make sure you understand the basic concepts behind projectile motion: specifically what happens in the x and y directions and how do these relate to one another. You should review how to do projectile motion problems in which the projectile is launched horizontally.

Conservation of Energy – Review conservation of mechanical energy, $E_i = E_f$ if there are only conservative forces. You should review how to do $E_i = E_f$ types of problems.

Conservation of momentum – Review the law of conservation of momentum. You should review how to do one-dimensional inelastic collision problems.

Equipment

The ballistic pendulum is a device used to catch a ball fired from a spring-powered gun. Just after the ball is launched a pendulum bob catches it. The pendulum bob and ball move off together after the collision (see Figure 1).

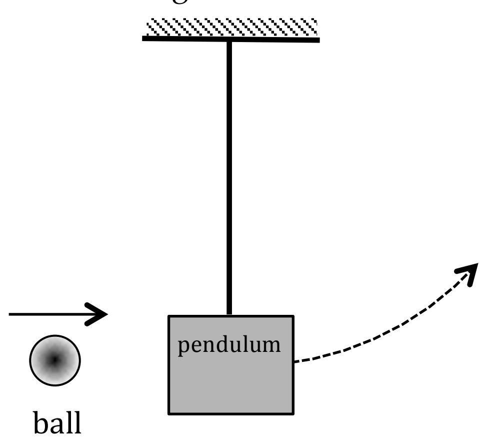

Figure 1

The apparatus includes a mechanism that records the maximum height the ball/pendulum bob combination attains after moving off together. Also, the effective center of mass of the ball and pendulum bob combination (or the distance to measure to so you can find the effective length of the pendulum bob combination) is marked on the pendulum.

Procedure

Please be careful with your launcher. Do not leave your launcher armed unless you are actively making a trial.

I. Preliminary analysis
Consider the 3 instances in the motion of the system below (Figure 2).

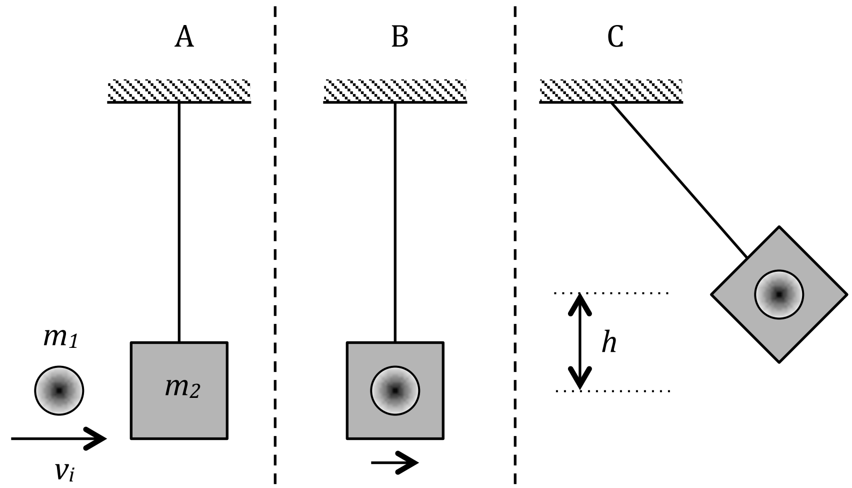

Figure 2

For Figure 2, A is immediately before the ball hits the pendulum, B is immediately after the ball is captured by the pendulum, and C is at the top of the swing of the ball/pendulum combination.

Answer the following.
1. Between A and B a collision occurs. Is this an elastic or inelastic collision?
2. Is momentum conserved during this collision?
3. Is kinetic energy conserved during this collision?
4. Between B and C, as the pendulum swings up, is momentum conserved?
5. Between B and C, as the pendulum swings up, is mechanical energy conserved?

II. Finding the initial velocity
Consider Figure 2 above. Develop a way to find the ball's initial velocity based on the height achieved by the ballistic pendulum. Use energy and momentum conservation principles to find v_i in terms of the variables m_1, m_2, h, and g.

III. Measuring mass and velocity
Find masses m_1 and m_2. To determine the velocity v_i fire the ball 10 times into the pendulum. Record the change in height of the pendulum for each trial. Use the tip of the arrow on the side of the pendulum as a reference point. Once these are found, find the average change in height and use this to find v_i.

IV. Predicting range of ball

Now that you know the initial velocity of the ball, you can use the principles of projectile motion to predict where the ball will land on the floor when it is fired from the tabletop with the pendulum removed. Show how to express the range R of the ball in terms of v_i g, and H (the height from the ground to the release point of the ball). See Figure 3.

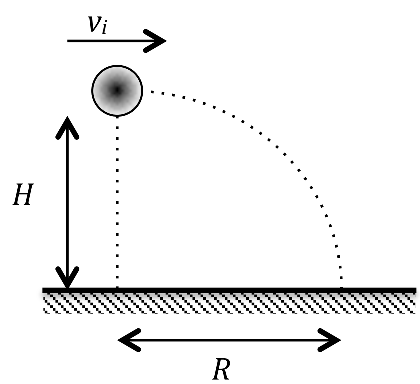

Figure 3

Measure H (should you measure from the bottom of the ball or the middle of the ball?) and calculate the predicted range of the ball.

V. Testing your prediction

Now we you need to locate the landing spot of the ball. Should you measure R from when the spring is compressed or when it is about to leave the launch mechanism? You can hang a plumb bob from the edge of the table and use a meter stick to help mark this location carefully. Tape a piece of white paper on the floor and mark the predicted landing spot with an 'X'.

When you are ready, ask your lab instructor to observe your test of your prediction. Cover the white paper with a piece of carbon paper and carry out a test shot.

***Make sure the firing range is clear before launching the ball ***

If the test shot seems reasonable carry out 4 more trials and record the actual range of each trial and find the average R_{av} of these. If your first test shot was not very close you should look over your measurements and calculations before proceeding with the extra trials.

Have one group member staple your paper with the landing marks to their report.

When finished with your lab please remove any tape from the floor and make sure your lab station is cleaned up.

Homework

1. Using your highest value of h, calculate the longest expected range, R_{max}. Using your lowest value of h, calculate the shortest expected range, R_{min}. Does your average measured value of range R_{av} lie in between these values? If it does not, comment on reasons why this value may not lie in between R_{max} and R_{min}.

2. Use R_{av} to calculate $v_{i,av}$, the initial velocity of the ball found from your average range and compare it to v_i, the initial velocity of the ball found from the collision with the pendulum. To compare find the % difference between them using

$$\% \text{difference} = \frac{|v_i - v_{i,av}|}{|v_{i,av}|} \text{ X } 100\%.$$

3. When shooting the ball into the pendulum, why can't we use energy conservation and say that all the initial kinetic energy of the ball goes into gravitational potential energy of the ball/pendulum combination at height h?

4. Suppose the collision with the ball and pendulum was an elastic collision and the ball bounced backwards when it strikes the pendulum. Would the pendulum go higher, lower, or to the same height it achieved with the inelastic collision from the experiment? Explain.