The Ballistic Pendulum

OBJECTIVE

To calculate the range of a projectile that is launched horizontally by a ballistic pendulum by applying Conservation of Energy and Conservation of Momentum.

EQUIPMENT

1. ballistic pendulum
2. carbon paper
3. tape
4. meter stick
5. pan balance

THEORY

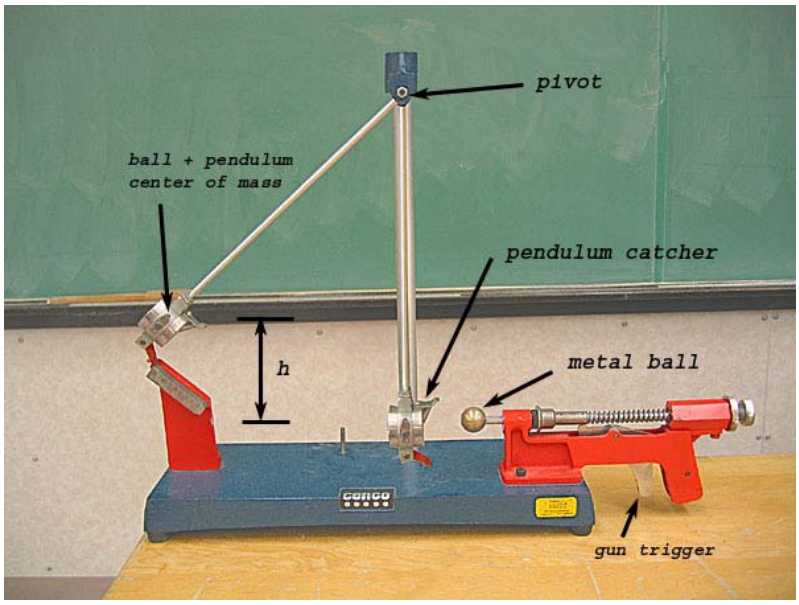

Figure 1

The apparatus shown in Figure 1 is called the ballistic pendulum. This device is used to determine the speed of fast moving projectiles. The projectile is launched horizontally into a pendulum and then swing together until they reach a maximum vertical height 'h'. Conservation of momentum and energy can then be applied to measure the initial speed of the projectile.

1. You will apply conservation of momentum to the ball + pendulum system immediately after the ball is fired and immediately after the pendulum catches the ball. By equating the initial momentum to the final momentum for this complete inelastic collision you will have an expression for the velocity of the ball immediately before the collision. The velocity of the ball V_b immediately before the collision will be in terms of the velocity V of the ball + pendulum system

immediately after the collision, the mass m_b of the ball, and the mass m_p of the pendulum. That is $V_b=V_b(m_b,m_p,V)$.

2. The masses m_b and m_p will be measure directly. We will now apply conservation of energy immediately after the collision and at the point when the ball + pendulum reach the maximum height '*h*'. This will allows to find an expression for V in terms of g and h. That is V=V(g,h).

3. Your expression for V_b can now be expressed in terms of m_b, m_p, g, and *h*. That is $V_b=V_b(m_b,m_p,g,h)$.

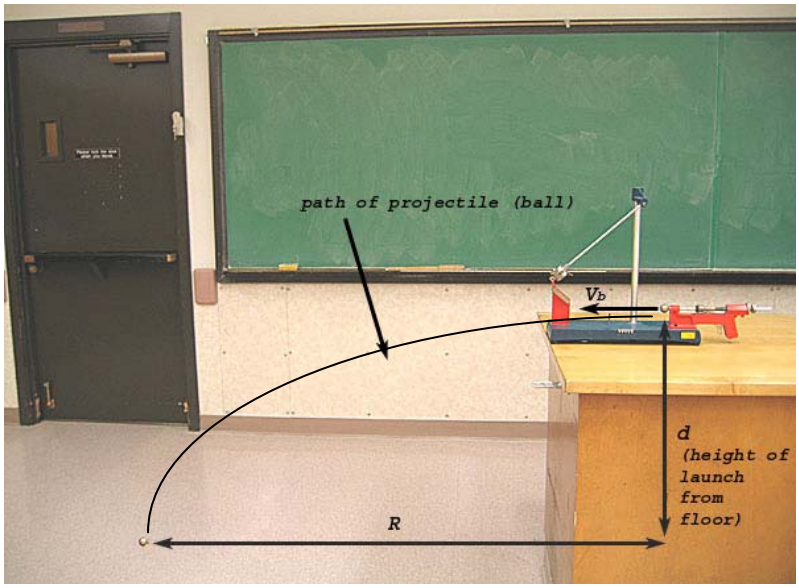

Figure 2

Knowing the speed of the ball V_b, we can now derive and expression for the horizontal range R of the ball if it was fired horizontally (with the pendulum swung out of the way). See Figure 2 above.

4. Apply the kinematic equations of motion at the point of launch to obtain an expression for the range R in terms of the velocity of the ball V_b, the height of launch *d* measured from the floor, and the acceleration of gravity *g*. That is $R=R(V_b, d, g)$. Substituting the expression for V_b in terms of $V_b=V_b(m_b,m_p,g,h)$ will give our final equation for the range R in terms of $R=R(m_b,m_p,d,h)$.

5. We will measure m_b, m_p, d, and h directly and calculate the range R of the ball using our final expression $R=R(m_b,m_p,d,h)$. You will compare this expected value of R to the experimental measured value of R when shooting the ball horizontally.

PROCEDURE

Part I (Calculating the expected value of R)

1. Setup the apparatus as shown in Figure 1. Level the platform with the level provided.
2. Locate the center of mass of the ball + pendulum system.
3. Measure the mass of the ball m_b with the pan balance. The mass of the pendulum m_p is marked on the pendulum.
4. Prepare the gun for firing by placing ball on gun rod and cocking the gun.
5. Place the pendulum at rest in its vertical position.
6. Pull the gun trigger.
7. Measure the height '*h*'. This is the vertical displacement of the center of mass of the ball + pendulum system.
8. Repeat (7) for a total of 5 runs.
9. Calculate the average value of '*h'* and use this average to calculate R. Take this to be the expected value $R_{expected}$.

Part II (Hitting the target at range R)

For this part of the lab you will be given a target to place on the floor. The objective of the game is to strike the target with the minimum number of shots. You will only be given a total of 5 shots. If you strike the target on the first shot everyone on the group will get 20/20 on their lab. For each additional shot your group will be deducted 2 points.

1. Setup the apparatus as shown in Figure 2.
2. Measure the height '*d*' from the point of launch of the ball to the floor.
3. Center your carbon paper at the point the ball is supposed to strike. This point should be given by the calculated value of $R_{expected}$ obtained in Part I. It is very important that your calculations for $R_{expected}$ are done correctly **and** that you place the target at the correct position so that you don't loose as many points.
4. With the pendulum out of the way, prepare the gun for firing just as you did in Part I above. **MAKE SURE THAT NOBODY IS IN THE PATH OF THE BALL! YOU CAN SERIOUSLY GET HURT IF YOU ARE STRUCK WITH THE BALL!**
5. Call the instructor so that he can witness whether the ball strikes the target or not. If you shoot the ball without having the instructor present, you will loose 2 points.
6. If you hit the target on the first shot, GREAT! Everyone in the group gets 20/20 on the lab. However, if you don't, you loose 2 points but you still have 4 additional shots to hit the target. GOOD LUCK!