Includes Teacher's Notes and Typical Experiment Results

Instruction Manual and Experiment Guide for the PASCO scientific Model ME-6815

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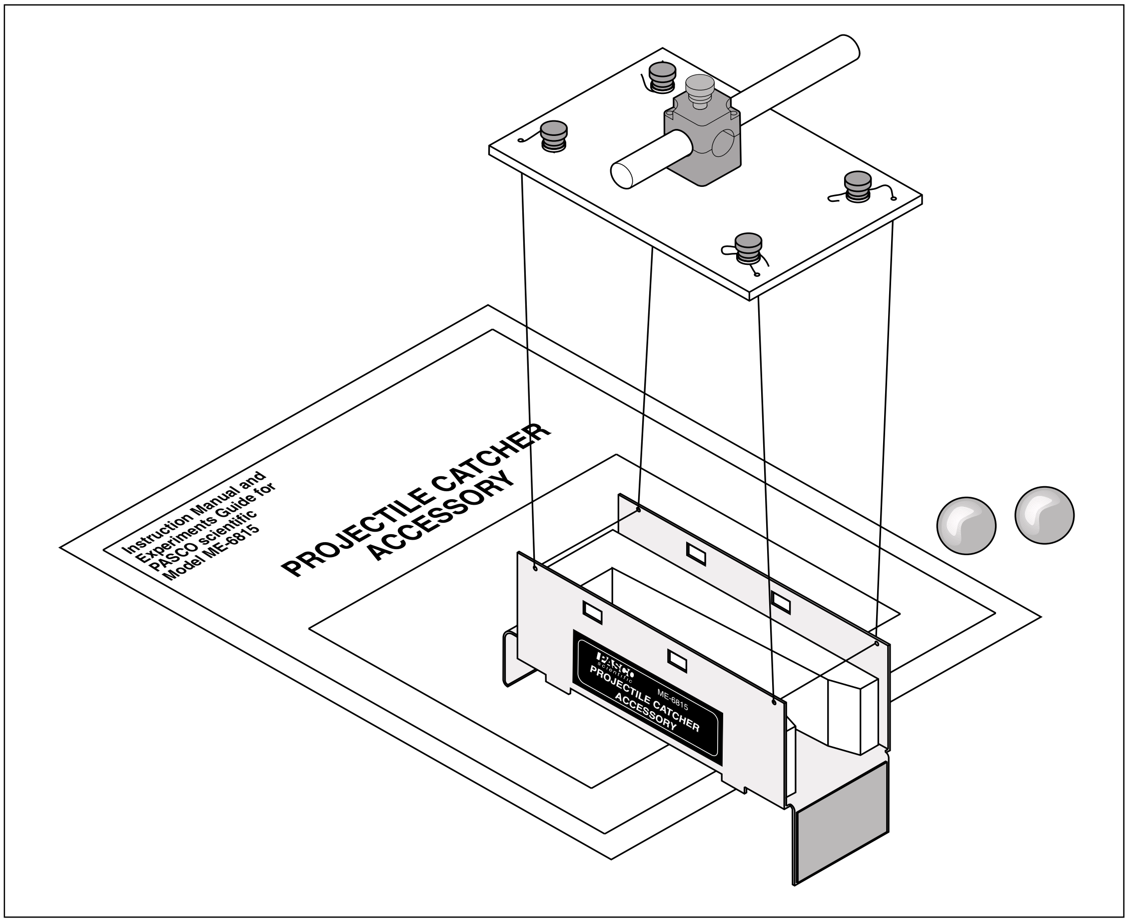
PROJECTILE CATCHER ACCESSORY



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① The packing carton must be strong enough for the item shipped.

② Make certain there are at least two inches of packing material between any point on the apparatus and the inside walls of the carton.

③ Make certain that the packing material cannot shift in the box or become compressed, allowing the instrument come in contact with the packing carton.

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Introduction

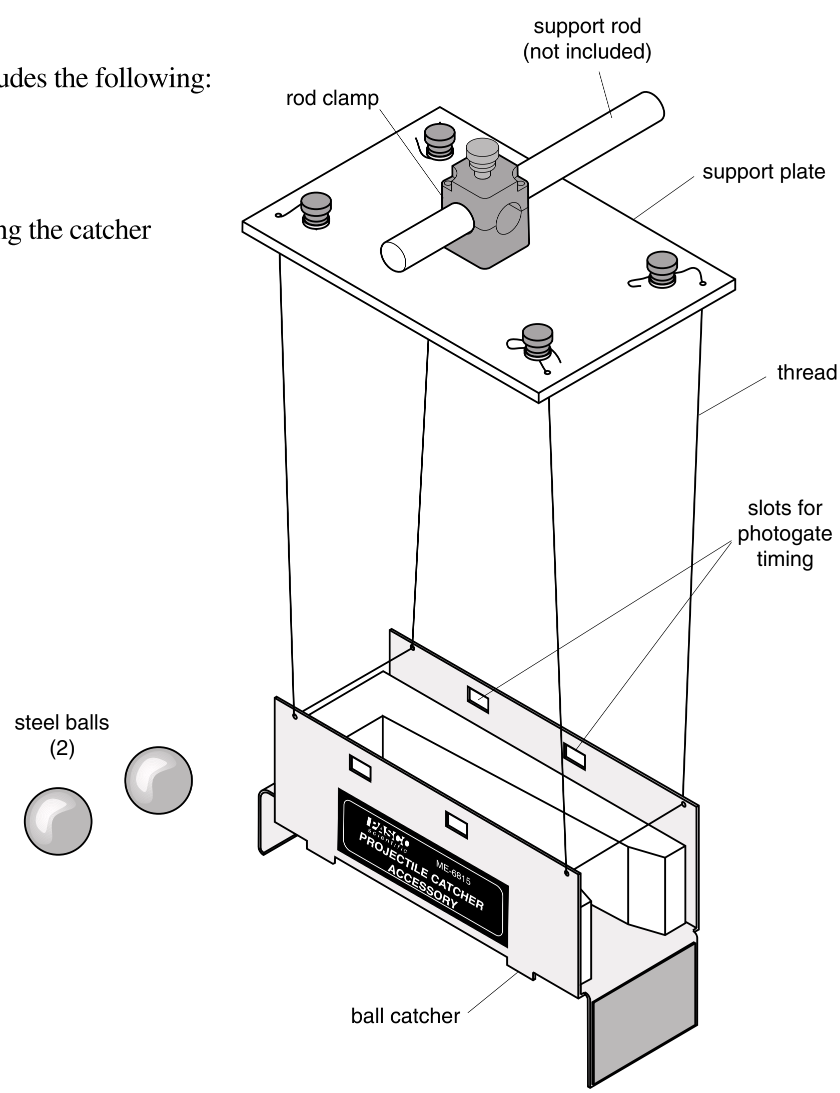
The PASCO ME-6815 Projectile Catcher Accessory has three functions:

- A Projectile Launcher is used to shoot a steel ball into the ball catcher which is mounted on a Dynamics Cart to show an inelastic collision.
- The steel ball can be bounced off the rubber bumper of the ball catcher to show an elastic collision between the ball and the cart.
- The catcher (without cart) can be suspended from strings and used with the Projectile Launcher as a ballistic pendulum.

Equipment

The Projectile Catcher Accessory includes the following:

- a ball catcher
- (2) steel projectile balls
- plate assembly from which to hang the catcher
- spool of thread
- Velcro® assembly



Projectile Launcher Setup

When using the Projectile Catcher Accessory with a PASCO ME-6800 or ME-6801 Projectile Launcher, follow these operation guidelines:

1. Please read the General Operations section of the *Projectile Launcher Manual* before using the Projectile Launcher with the Projectile Catcher Accessory or any other accessory.

   Safety goggles are supplied with the Projectile Launcher and must be worn when operating the apparatus.

2. The base of the Projectile Launcher must be clamped to a sturdy table using the clamp of your choice. When clamping to the table, it is desirable to have the label side of the launcher even with one edge of the table so a plumb bob can be used to locate the position of the muzzle with respect to the floor.

3. Mount the Projectile Launcher in a horizontal position, using the two lower slots in the Projectile Launcher base, as shown in Figure 1.

4. Establish the height at which the Projectile Launcher should be fired and tighten the thumbscrews as required.

WARNING: Never look down the front of the barrel of the Projectile Launcher because it may be loaded.

To check to see if the ball is in the barrel and whether the Projectile Launcher is cocked, look at the slots in the side of the barrel. The yellow indicator seen through the slot indicates the position of the piston and the ball can be seen through these slots when it is in the piston. *Wear safety goggles for eye protection.*

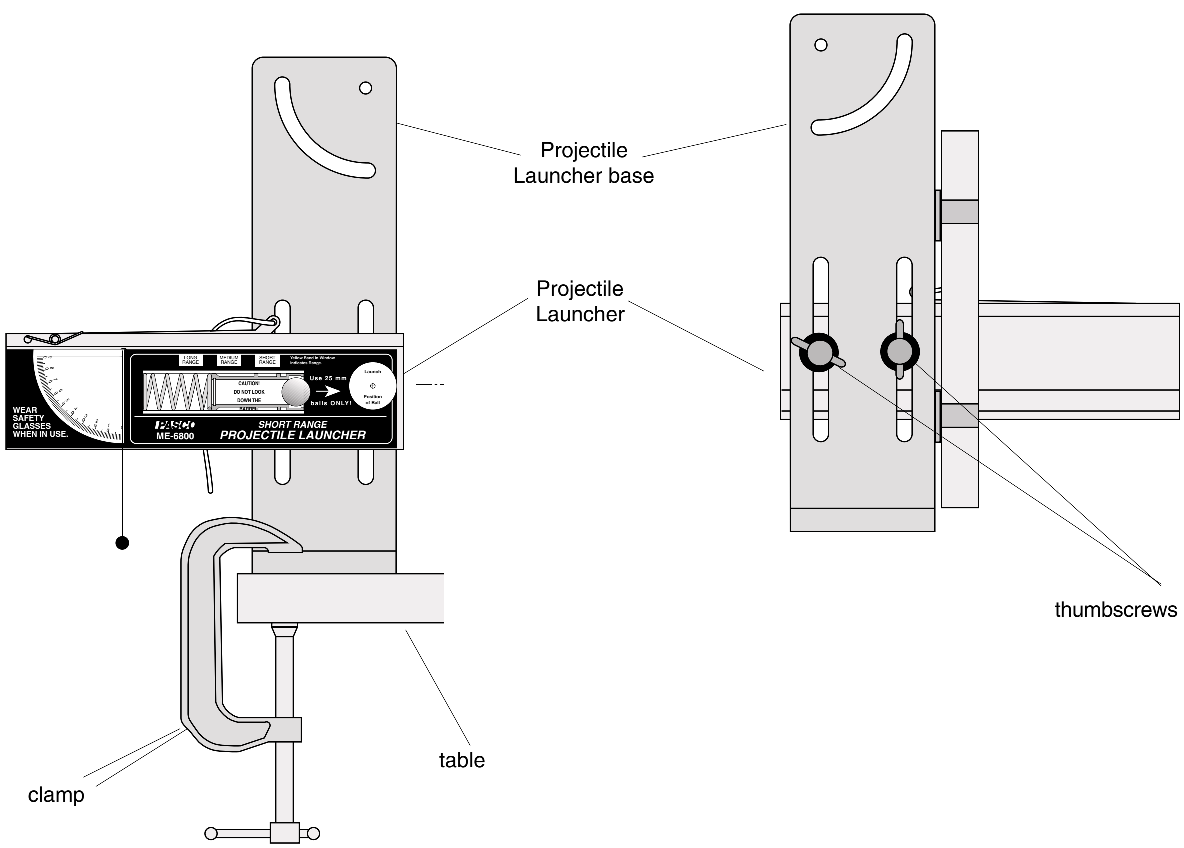


Figure 1: Projectile Launcher Setup

Ball Catcher Setup

Suspending the Ball Catcher as a Pendulum

Secure the rod clamp on top of the support plate to a support rod that is clamped to the table. Cut two pieces of string, each about two meters long. Thread one string through the front two holes in the ball catcher. Thread the other string through the back two holes in the ball catcher. Refer to the diagram below on how to attach the string. Thread the ends of the strings through the holes in the support plate and secure them, making sure the catcher hangs level.

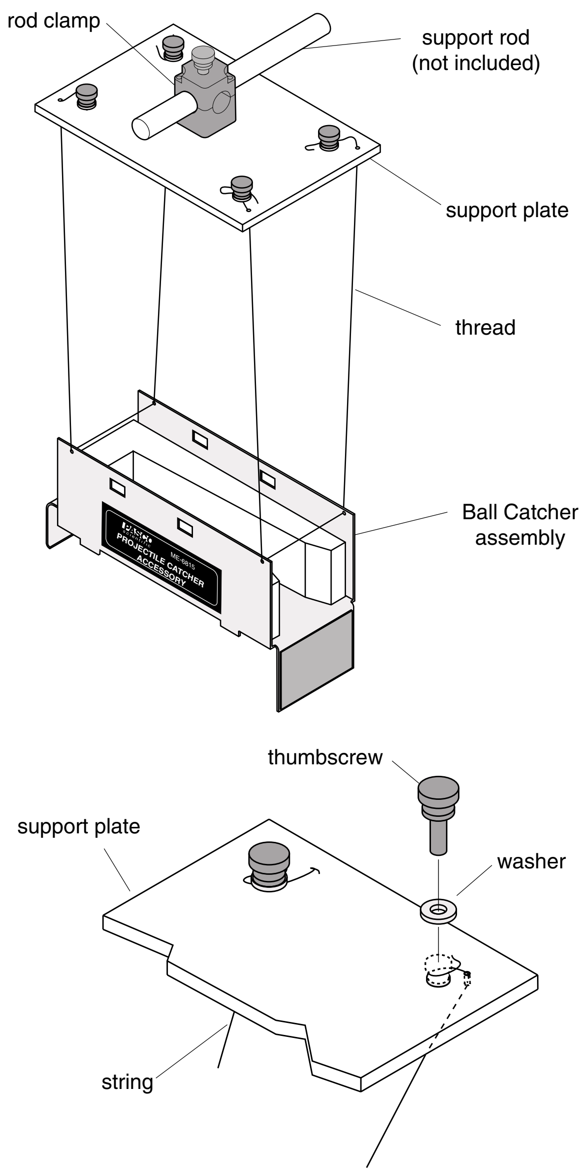


Figure 2: Suspending the Ball Catcher

Velcro Assembly

You may want to quantify and record the results of your experiments. To enable the user to measure the height to which the pendulum swings, a thread must be connected between the ball catcher and the launcher. The launcher end slips through a Velcro assembly, and the amount of extension of the string shows how far the pendulum swung. See Figure 3.

1. Separate the Velcro hook and loop strips.
2. Cut two square pieces of Velcro loop and one square piece of Velcro hook.
3. Determine the approximate height at which the Velcro assembly will be applied. This is determined by the approximate height at which the ball catcher hangs.
4. Remove the protective covering from the back of each Velcro square.
5. Arrange the two square pieces of Velcro loop and one square piece of Velcro hook onto the vertical plate of the Projectile Launcher base as shown.
6. Cut one piece of Velcro hook 5 – 6 cm long. Do not remove the protective backing.
7. Tie a thread to one of the front holes in the ball catcher.
8. The other end of this thread will pass between the square piece of Velcro hook (attached to the Projectile Launcher base) and the long piece of Velcro hook, which should be applied to the three Velcro squares attached to the Projectile Launcher base.

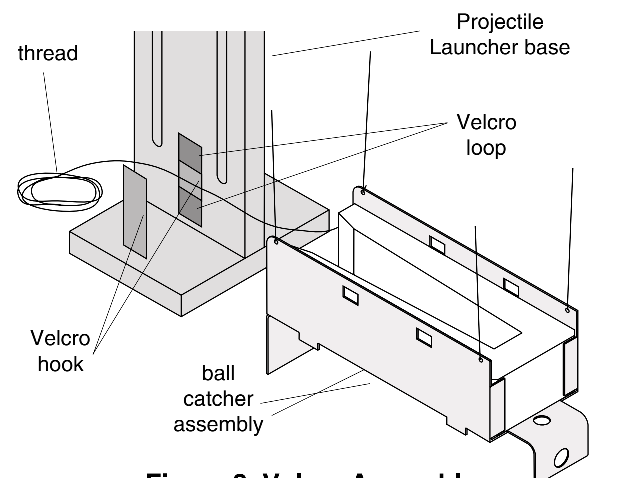


Figure 3: Velcro Assembly

Exp 1: Ballistic Pendulum

EQUIPMENT NEEDED

– Projectile Launcher (ME-6800)
– Projectile Catcher Accessory (ME-6815)
  [Velcro must be assembled (See Figure 3)]
– Base and Support Rod (ME-9355)
– table clamp

-meter stick
-white paper
-carbon paper
-mass balance

Optional: Photogates and Photogate Bracket

Purpose

The muzzle velocity of the Projectile Launcher can be determined by shooting the ball into a ballistic pendulum and then measuring the height reached by the pendulum.

Theory

A ball is launched horizontally and embeds in the bob of a pendulum. The pendulum then swings up to a particular height, h. (See Figure 1.1.)

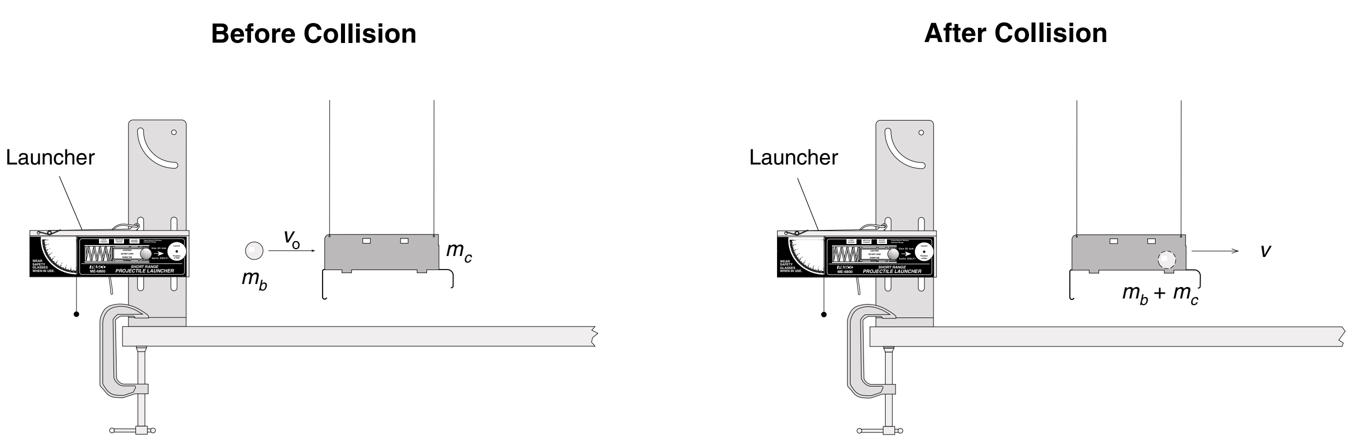


Figure 1.1: Conservation of Momentum

Momentum is conserved during the collision, but kinetic energy is not. The momentum after the collision is equal to the momentum before the collision:

$$(1) \quad m_b v_o = (m_b + m_c)v$$

where m_b is the mass of the ball, v_o is the muzzle velocity of the ball, m_c is the mass of the catcher, and v is the velocity of the catcher (and ball) after the collision.

The kinetic energy of the catcher (and ball) after the collision is converted completely to potential energy at the top of the swing:

$$(2) \quad \frac{1}{2}(m_b + m_c)v^2 = (m_b + m_c)gh$$

To find the muzzle velocity of the ball, we begin with the potential energy of the pendulum at the top of its swing and work backwards from there. From our equation for energy conservation (2):

(3) $v = \sqrt{2gh}$

Substitute (3) into the equation for momentum conservation (1):

$$m_b v_o = (m_b + m_c)\sqrt{2gh}$$
$$v_o = \left(\frac{m_b + m_c}{m_b}\right)\sqrt{2gh}$$

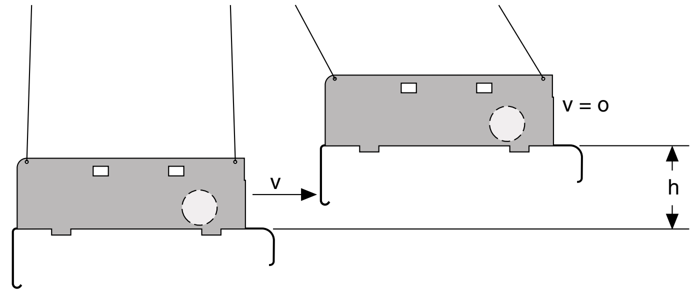


Figure 1.2: Conservation of Energy

For comparison, the initial speed (muzzle velocity) of the ball is determined by shooting the ball horizontally off the table onto the floor and measuring the vertical and horizontal distances through which the ball travels.

For a ball shot horizontally off a table with an initial speed, v_0, the horizontal distance ("x") traveled by the ball is given by $x = v_0 t$, where t is the time the ball is in the air. Air friction is assumed to be negligible.

The vertical distance the ball drops in time t is given by $y = \frac{1}{2}gt^2$.

The initial velocity of the ball can be determined by measuring *x* and *y*. The time of flight of the ball can be found using

$$t = \sqrt{\frac{2y}{g}}$$

and then the muzzle velocity can be found using $v_o = \frac{x}{t}$.

Part I: Determining the Initial Velocity of the Ball

Set Up

1. Clamp the Projectile Launcher to a sturdy table (near one end of the table).
2. Adjust the angle of the Projectile Launcher to zero degrees so the ball will be shot off horizontally, away from the table onto the floor.

Procedure

1. Put the steel ball into the Projectile Launcher and cock it to the long range position. Fire one shot to locate where the ball hits the floor. At this position, tape a piece of white paper to the floor. Place a piece of carbon paper (carbon-side down) on top of this paper and tape it down. When the ball hits the floor, it will leave a mark on the white paper.
2. Fire about ten shots.

3. Measure the vertical distance from the bottom of the ball as it leaves the barrel (this position is marked on the side of the barrel) to the floor. Record this distance in Table 1.1.
4. Use a plumb bob to find the point on the floor that is directly beneath the release point on the barrel. Measure the horizontal distance along the floor from the release point to the leading edge of the paper. Record in Table 1.1.
5. Measure from the leading edge of the paper to each of the ten dots and record these distances in Table 1.1.
6. Find the average of the ten distances and record in Table 1.1.
7. Using the vertical distance and the average horizontal distance, calculate the time of flight and the initial velocity of the ball.

   Record in Table 1.1 and Table 1.4.

Table 1.1: Determining the Initial Velocity

Vertical distance = _______________.

Horizontal distance to paper edge = ____________.

Initial velocity = ________________.

Trial Number	Distance
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
Average	
Total Distance	

Alternate Method: Determining the Muzzle Velocity with Photogates

1. Attach the Photogate Bracket to the launcher and attach two Photogates to the bracket. Plug the Photogates into a computer or other timer.
2. Put the ball into the Projectile Launcher and cock it to the long range position.
3. Run the timing program and set it to measure the time between the ball blocking the two Photogates.
4. Shoot the ball three times and take the average of these times. Record in Table 1.2.
5. Use a distance of 10 cm (between the Photogates) to calculate the initial speed. Record the initial speed in Table 1.2 and Table 1.4.

Table 1.2: Initial Speed Using Photogates

Trial Number	Time
1	
2	
3	
Average Time	
Initial Speed	

Part II: Ballistic Pendulum

Set Up

1. Find the masses of the ball and catcher. Record in Table 1.3.
2. Suspend the ball catcher as a pendulum, as explained in the general instructions.
3. With the Projectile Launcher mounted as in Figure 1.1, clamp the suspended ball catcher directly in front of the muzzle.
4. Attach a thread to the ball catcher and string it through the Velcro assembly (see the general instructions) on the base of the Launcher.

Procedure

1. Load the Launcher (set to long range) with the steel ball. Fire a test shot to see how far out the thread is pulled. Pull a few centimeters of the thread back through the Velcro, leaving the rest of the thread slack between the Launcher and the catcher. When the ball is shot into the pendulum again, the thread will become taut just before the catcher reaches its maximum height. This reduces the effect of friction on the thread.
2. Fire the ball into the pendulum five times. After each trial, pull the pendulum back until the thread is taut and measure the height above the level of the muzzle to which the pendulum swung. Record in Table 1.3.

Analysis

1. Calculate the average of the heights in Table 1.3. Record the result in Table 1.4. Using the average height, calculate the velocity immediately after the collision and record it in Table 1.4.
2. Using the velocity calculated in the previous step and the masses, calculate the muzzle velocity of the ball and record in Table 1.4.
3. Calculate the percent difference between the muzzle velocities found in Parts 1 and 2. Record in Table 1.4.

Table 1.3: Ballistic Pendulum Data

Mass of Ball = _____________.

Mass of Catcher = __________.

Height

Table 1.4: Results

Average Height	
Velocity, v	
Calculated Muzzle Velocity, v_o	
Muzzle Velocity (Part 1)	
% Difference	

Questions

1. What percentage of the kinetic energy is lost in the collision? Use the masses and velocities to calculate this percentage:

$$\%Lost = \frac{KE_{before} - KE_{after}}{KE_{before}} \; x \; 100\%$$

2. How does the height to which the pendulum swings change if the ball is bounced off the rubber bumper on the front of the catcher instead of being caught?

   Try it, but be sure to move the catcher farther away from the Launcher so the steel ball won't rebound into the Launcher and damage the Launcher.