**The Ballistic Pendulum and Projectile Motion** Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Partner(s):\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Purpose:** To determine the initial velocity (u) of a projectile

A) By measuring its range and vertical distance of fall

B) By using the conservation of energy and momentum.

**Apparatus**: Ballistic pendulum, meter stick, white paper, carbon paper, tape, electronic balance, plumb-line, and small ruler.

**Theory:**



Using the kinematic equations for the above projectile motion, [derive an expression](https://youtu.be/by84EfLA498) for the initial horizontal velocity, u of the projectile in terms of Y, vertical distance of fall and g, acceleration due to gravity, and X, horizontal distance of travel.

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The collision is completely inelastic. The momentum is conserved but the kinetic energy is not conserved. During the collision, some of the energy is lost as heat. After the collision the energy is conserved. Just after the collision the pendulum & ball has kinetic energy and it is converted into gravitational potential energy when the pendulum & ball are raised to a height.

Use the conservation of momentum for the collision and conservation of energy after the collision, for raising the pendulum, and [derive an expression](https://youtu.be/fYMUtxZRlEs) for u in terms of m, M, g, h2, and h1.

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Among the quantities you need to measure in this lab, which one(s) will have the highest error?

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Procedure:

**A) Measurement of the range and fall of a projectile.**

1) Support the pendulum on the pawl and get the gun ready for firing.

2) The ball is fired horizontally to hit the floor. Fire the ball and determine approximately where it strikes the floor. Place a sheet of white paper on the floor so that the ball will hit it and secure the white paper to the floor with some tape. Place a carbon paper over the white paper, do not tape the carbon paper to the white paper, just place it over. Fire the ball 4 more times.

3) Draw a small circle encompassing all the spots, center of this circle is the average spot for range. Measure the range X (horizontal distance from the center of the circle to the launch point) and the vertical distance of fall, Y as shown in the diagram and complete the data table.

**B) Ballistic pendulum**

4) Get the gun ready for firing. Allow the pendulum to hang freely. When the pendulum is at rest, fire the ball into the pendulum bob. Record the notch number on the scale reached by the pawl when it catches the pendulum. Remove the ball from the pendulum.

5) Repeat procedure (4) 4 more times.

6) Compute the average value of the notch number. Set the pendulum with the pawl engaged in the average notch number, measure the height h2 from the base of the apparatus to the index point on the pendulum.

7) With the pendulum hanging in its lowest position, measure the height h1, from the base of the apparatus to the index point.

8) Record the mass of the pendulum, measure the mass of the ball, and complete the data table.

DATA TABLE:

A. Determination of the initial velocity (u) of a projectile from range and fall measurements:

Vertical distance of fall = Y = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Time of flight = t = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Average range = X =\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Initial velocity = u =\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

B. Determination of the initial velocity (u) of a projectile using ballistic pendulum method.

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|  Trial # |    1 | 2 | 3 | 4 | 5 |
| Notch # of Pendulum Catch |  |  |  |  |  |

Average notch # =\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Height h2 of pointer with pendulum catch in average notch number =\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Height h1 of pointer with pendulum freely suspended =\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Mass of ball                             m = \_\_\_\_\_\_\_\_\_\_\_\_

Mass of pendulum                   M= \_\_\_\_\_\_\_\_\_\_\_\_\_\_

Velocity of the pendulum & ball just after collision = V = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Initial velocity,   u = \_\_\_\_\_\_\_\_\_\_\_\_ [% difference](http://phoenix.phys.clemson.edu/tutorials/error/index.html) between results of parts A and B = \_\_\_\_\_\_\_\_\_

Use your data for part (B), in SI units, to answer the following questions.

1) Calculate the kinetic energy of the ball before the collision.

2) Calculate the kinetic energy of the ball and the pendulum bob just after the collision.

 3) Calculate the energy loss due to the collision.

4) What fraction of the initial kinetic energy is lost?

5) Fraction of the initial kinetic energy lost = $\frac{M}{m+M}$. Calculate the ratio, and compare it.

6) What happened to the lost energy?

**C) Write a conclusion**.