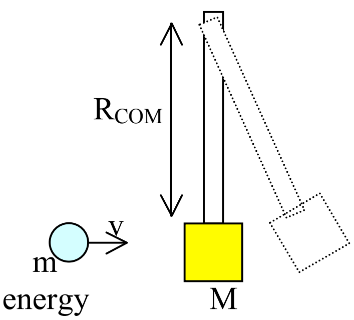
EXPERIMENT 6 BALLISTIC PENDULUM

Although we have the advantage of computer methods to measure short times and other previously difficult to measure quantities, it is sometimes useful to use our knowledge of physics to determine quantities indirectly, rather than by direct measurement, if only because some quantities can only be found by indirect methods. The ballistic pendulum is a good example of this principle. We will measure the speed of a projectile by using conservation laws, and then use equations of kinematics to predict the landing spot of a projectile.

BACKGROUND

The ballistic pendulum is a classic example of a device to calculate the speed of high-speed objects by making simple measurements. A launcher will use a spring to project a steel or plastic ball with high speed. This is the "ballistic" part of the name of the apparatus. A ball catcher is attached to the end of a pendulum device, so that the pendulum will swing up after it catches the ball. From conservation of mechanical energy we can calculate the speed of the catcher and ball after the collision, and then the conservation of momentum allows us to calculate the speed of the ball before the collision. The method is not exact, but can yield useful results. If you need help in deriving expressions below, look at Sample Problem 9-8 in your textbook.

ADVANCE STUDY ASSIGNMENT



1. Show that the rise in height of the center of mass of the pendulum sketched at right is $R_{COM}(1 - \cos\theta)$ where θ is the angle between the pendulum arm in the two positions.
2. Write an expression for the change in gravitational potential energy as the pendulum moves to the dotted position from the initial position. Note that the mass to be used is M + m.
3. Derive an expression for the speed, V of the pendulum just as it starts moving towards the dotted position. This is calculated by conservation of mechanical energy.
4. Finally, derive an expression for the speed of the ball before the collision. This is calculated by conservation of momentum during the collision.
5. Derive an expression for the horizontal range of a projectile launched horizontally with initial speed v, a distance h above a level floor. You may find chapter 4 a helpful review.

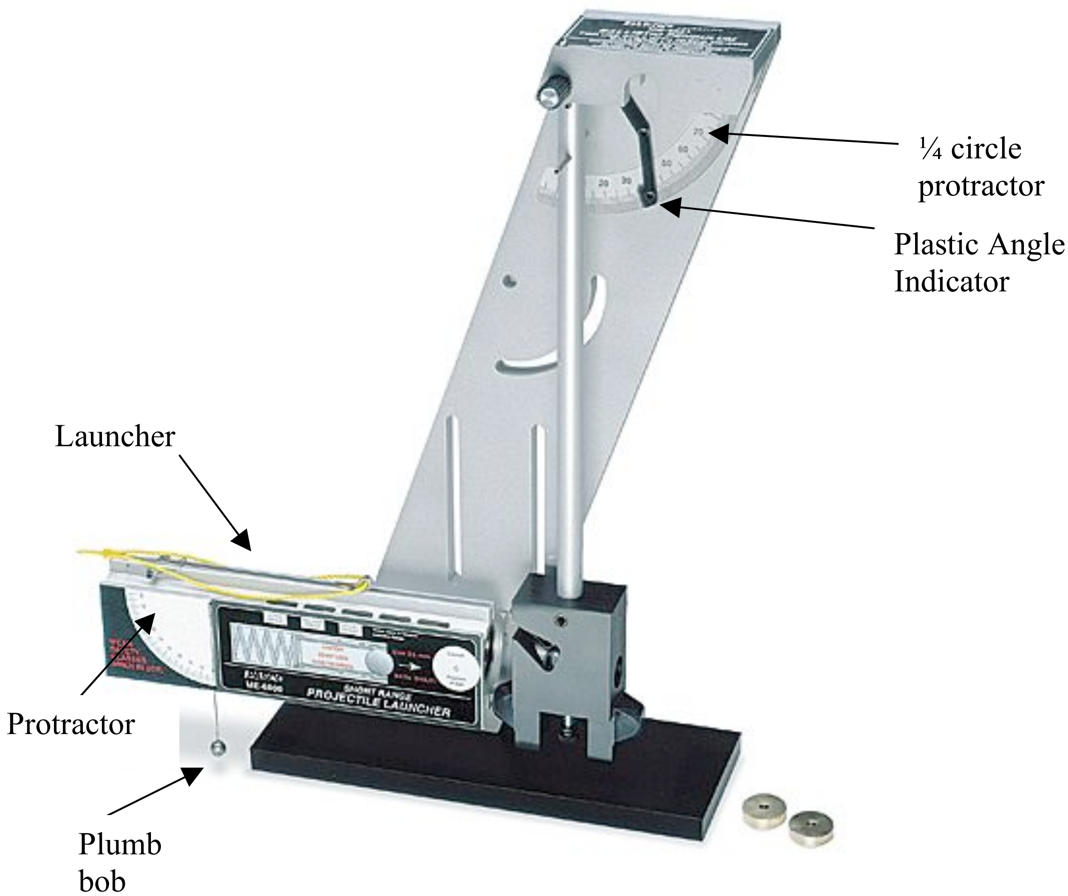
CAUTIONS

1. For the following parts of the experiment, be sure never to look into the barrel of the launcher. You cannot always tell if it is loaded.
2. Each time before you fire the launcher, be sure no one is walking in the intended target area.

3. Never push the ramrod into the launcher without a ball.

PROCEDURE A

1. Notice the parts of the ballistic pendulum in the sketch below. Note the plumb bob with protractor, the launcher, the pendulum, and the plastic angle indicator on the vertical part of the main base with the angle markings in a quarter circle.



2. Remove the pendulum and determine its mass, M. Record this in Data Table A. While the pendulum is removed, determine the center of mass (with the ball in the pendulum catcher), either by suspending the pendulum from a loop of string so it balances, or balancing it on a pencil on the table. When you have determined the center of mass, measure the length from the pivot axis to the center of mass. Record this as R_{COM} on Data Table A
3. Record the mass of the ball, m, on Data Table A.
4. You are now ready to measure the angle, which will allow you to calculate v with the formulas you derived in the Advance Study Assignment. Place the pendulum back on its pivot on the apparatus (with the open end of the catcher towards the launcher), and latch it out of the way for now. Next, using the ramrod, push a ball against the spring, past the first position until it clicks in the second available position. Now lower the

pendulum so the catcher is next to the launcher. Make sure the plastic angle marker is at the lowest reading.

5. Release the spring, by pulling up on the string attached to the release lever on top of the launcher. The pendulum should catch the ball, swing up, and push the plastic angle indicator to show the highest angle. Record the angle on Data Table A, as θ_o. Now set the angle indicator at an angle 2° smaller than θ_o and repeat the procedure three times, recording the angles measured on Data Table A.
6. Use the average value of the three angles to calculate v of the ball before collision.

PROCEDURE B

7. Place the ballistic pendulum, with the pendulum latched out of the way, on the edge of the table, aimed horizontally. It should be clamped into position. Measure the vertical height of the middle of the launcher barrel above the floor by using a two-meter stick and caliper jaw. Record this height as h in Data Table B. Using a plumb bob, place a small coin (penny or dime) under the plumb bob on the floor.
8. Using the formula you derived in Advanced Study Assignment 5, calculate the expected horizontal distance the ball will travel when launched as you have measured, h above the floor. Record this as R_{PRE} on Data Table B.
9. With masking tape, tape a paper towel on the floor at R_{PRE} and mark the expected impact site of the ball on the paper towel.
10. Place a wooden box with foam inside it standing behind the expected impact location, to stop the ball.
11. Now again place the ball in the launcher, use the ramrod to push the ball to the second (middle) available launch position, and release it. Do this 5 times, and measure the distances R_{EXP} and record on Data Table B. Calculate and record the average value. Calculate the percent difference between R_{PRE} and R_{EXP} record.

QUESTIONS

1. Is it possible to use conservation of energy in one step, in the form $\frac{1}{2}mv^2 = (M+m)gh$ to find the initial speed of the ball? Explain your answer.
2. How close were the repeated hits of the ball on the paper towel to each other?
3. How close was R_{PRE} to R_{EXP}? Can you think of any reasons for the difference?
4. How close was θ_o to θ? Can you think of a reason for this step (procedure 5)?

DATA TABLE A

M ________________ Calculation for v

R_{COM} ________________

M ________________

θ_o ________________

θ ________________

________________ $\bar{\theta}$ ______________

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v ________________

DATA TABLE B

h ________________ Calculation for R_{pre}

R_{pre} ________________

R_{exp} ________________

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________________ Calculation for % diff

$\bar{R}_{exp}$ ________________

% diff ________________