

TEACHER NOTES

LAB MECH 8. COMP

RELATED TOPICS

Vector Analysis
Acceleration due to gravity
Velocity components

STANDARDS ADDRESSED

Science and Technology

3.1.10, 3.1.12

3.2.10, 3.2.12

3.4.10, 3.4.12

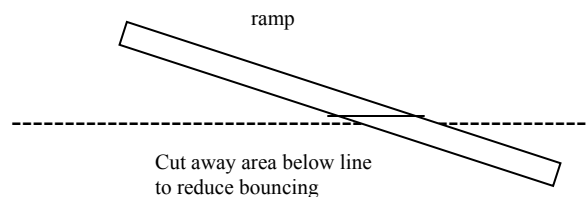
3.7.10, 3.7.12

CONSIDERATIONS

1. This is a favorite experiment of many teachers. The students enjoy the challenge of hitting a target. You may want to award bonus points for successfully predicting the impact within the predicted limits. If you do this, make strict rules that the students must not allow the ball to reach the floor during the timing runs.
2. You can make a good target cup by cutting off the bottom centimeter or so of a paper cup. Do not use an unmodified cup because an on-target ball may strike the side of the cup. Our target will be a sheet of paper taped to the floor and then placing a sheet of carbon paper, carbon side down on the sheet of paper. For such to work well assumes using firm balls, such as metal spheres.
3. Encourage students to algebraically solve the projectile motion problem in Step 10 of the Analysis section (that is, without numbers), since they will evaluate the function three times.
4. If the distance between the Photogates is not measured accurately, all speed measurements will be systemically low or high. This measurement is the most critical of the experiment, especially if the Photogates are close together, yet is the easiest to do poorly. It is important that the Photogates be positioned parallel to one another.
5. To avoid the Photogate-to-Photogate measurement problem, the experiment can also be done with a single Photogate. The number of Photogates required for the class is also cut in half. In this case, the experiment file must be modified so the timing mode is set to Gate Timing – One Gate, set in the Setup | Data Collection | Sampling tab. Enter the ball diameter in the Length of Object field, in units of meters. With one gate, it is important that the Photogate be set so that its beam strikes the ball at the center. If it does not, the effective diameter of the ball is different from what is entered, and so all speed measurements will be systematically incorrect. The proper positioning of the Photogate

height becomes the critical setup, in place of the Photogate-to-Photogate distance measurement in the two Photogate version. A larger ball, such as a racquetball, will make the Photogate placement less critical. Be sure the ball does not strike the Photogate.

6. The experiment can also be done with toy cars instead of a ball. If you are doing the single-Photogate version of the experiment, the Object Length entered in *Logger Pro* must be the length of the car *at the Photogate beam height*.
7. There are a number of ways to account for variations in the velocity measurement in the range prediction Δx . Depending on the mathematical sophistication of your students, use either the average \pm standard deviation or the minimum and maximum speeds as extreme values for the speed. Calculate the range for each extreme value, creating a range of predictions.
8. For the most accurate speed measurements and the best predictions of target location, you can determine the distance between Photogates using *Logger Pro*. This will allow for any optical differences in the Photogates. To do this, have *Logger Pro* running and very slowly move the ball along the track toward the first Photogate. Carefully note the exact position when Photogate 1 registers as Blocked. Mark this spot on the track. Repeat this for Photogate 2. Use the distance between the marks as the distance between the Photogates.
9. If you hold a competition among your students in predicting the impact point, note that fine distinctions are often statistically impossible to defend. For example, suppose one group predicts a range of 0.78 ± 0.03 m, and another 0.72 ± 0.04 m. The actual impact points are 0.76 and 0.71 m, respectively. It would be wrong to say that the second group was “closer” in their experiment, since the impact was within the predicted range for both groups. It was simple random variation that caused the second group to have a strike that is closer to the center of the predicted range than the first. If the trials were repeated, it is possible that the first group’s deviation from the center of the impact range would be closer. Both groups are equally successful, and to rank the groups as second and first cannot be defended statistically. Give the groups equal prizes or bonus points.
10. A variety of different ramp materials can be used. Corner molding, angle molding, metal U-channel, etc. have all been used to good advantage. Care must be taken to reduce bouncing of the ball. We recommend shaving back the bottom edge of your ramp. This will allow the ball to move from the ramp to the table with a minimum of bouncing. A bounce could cause the ball to miss the photogate beam.



SAMPLE RESULTS

Typically, students will predict a spot a centimeter or so too far out. This is because of the frictional slowing of the ball both on the track after the Photogates and in the air. Note that in this lab, we are really measuring the average velocity between the Photogates, which is the speed of the ball somewhere between the two Photogates.

ANSWERS TO PRELIMINARY QUESTIONS

1. Since the ball is starting from rest, the distance from the release point to the floor must be known in order to calculate the time of the fall. We assume that the acceleration is constant and equal to g . We also would assume that air resistance is negligible.
2. The distance it travels horizontally is $v_h \times t$.
3. The distance Δs between the two Photogates must be used with the time interval Δt to calculate a speed using $\Delta s / \Delta t$.

ANSWERS TO PROCEDURE QUESTIONS

8. The average velocity represents the set of all five measurements.
10. The distance from the floor origin is calculated from

$$\Delta x = v_{0x} \sqrt{\frac{2h}{g}}$$

Where h is the table height and v_{0x} is the average speed measured by the Photogate. We assume $v_{0y} = 0$ since the ball is initially moving horizontally. We also assume $a_x = 0$ since there is no force in the horizontal direction, and $a_y = g$. The relationship is obtained by noting that the time to fall a distance h is the same as the time to move the horizontal distance Δx . Eliminating time between the vertical and horizontal component equations then gives the expression above.

ANSWERS TO ANALYSIS QUESTIONS

1. Any calculation using uncertain measurements is itself uncertain, so the prediction cannot be exact. A range of predicted values is more appropriate than a single value.
2. Explain to your students that they should predict a target range rather than a target spot. The range depends on the uncertainty in measurements used in the calculation. As long as the actual impact point is somewhere between the minimum and maximum distances, *where* the ball strikes within the range depends on random variations.

3. In addition to variations in the speed measurement (which is itself affected by the Photogate spacing) the table height h may be different from the measured value. Also, the table may not be level, projecting the ball so it does not start out horizontally.
4. No account of air resistance is made in this analysis. If air resistance is important then the ball falls short of the predicted impact point. (Try a Styrofoam ball.)