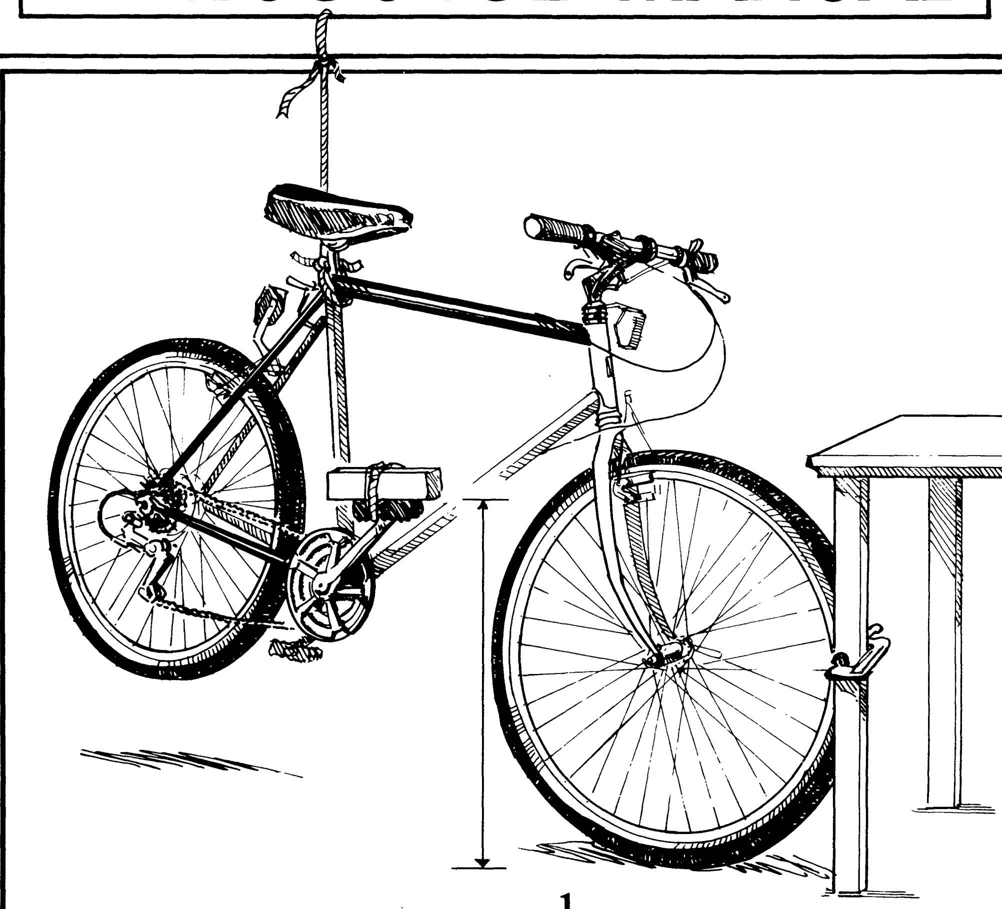
Practical Physics Labs

A RESOURCE MANUAL



$$mgh = \frac{1}{2}I\omega^2$$

Peter Goodwin

illustrated by Nicholas Soloway

J. Weston Walch, Publisher

Portland, Maine

Contents

Lab #13
A Collision in Two Dimensions

Name: ______________________________

Date: ______________________________

In this lab you will investigate collisions in two dimensions. Two balls are used. The first ball rolls down an incline and then hits another. The collision causes the balls to move at different angles. The horizontal distance which each flies will be measured as well as the direction of the flight. These data will allow you to see if momentum has been conserved.

Materials

clamp	string
ramp	washer
tape	pencil
paper	meter stick
2 balls of equal mass	protractor
carbon paper	

Procedure

1. Clamp the ramp so that the lower end is just off the edge of the table. Make sure the ramp is horizontal at the table edge. See Figure 13.
2. Take some string long enough to reach from the end of your ramp to the floor and tie a washer on it. Hold the string at the end of the ramp so that the washer is just off the floor. Gravity makes the washer hang vertically and you can find the point right under your ramp. Tape a piece of paper to the floor under the washer and then mark this point with an *X*.
3. Place a ball at the highest point and release it. Note approximately where it lands.
4. Tape a piece of white paper to the floor with its center approximately where the ball landed. Then place a piece of carbon paper over the white paper.
5. Roll the ball down the ramp from the top. When it hits the carbon paper it leaves a dot on the white paper. Roll the ball down the ramp a few more times.
6. With a meter stick, measure the distance from each of your dots to the *X*. Record these values.
7. Draw a line on the paper from the *X* on your paper under the ramp toward the middle of the black dots where the ball landed.

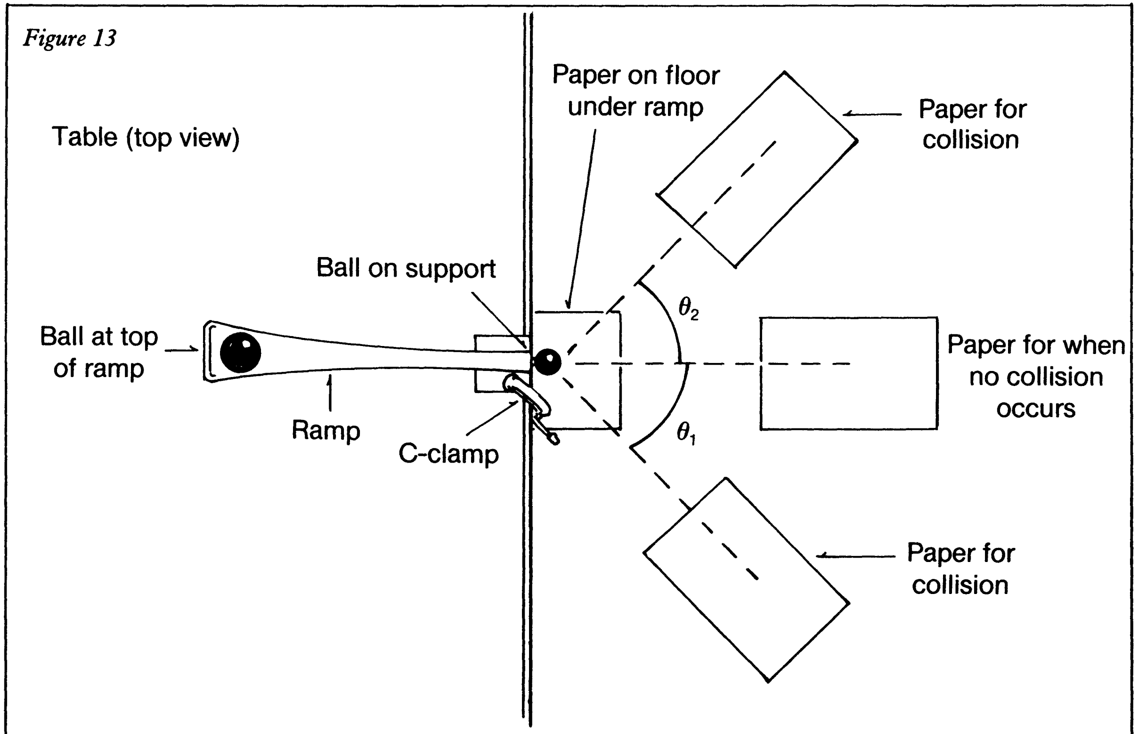
(continued)

Lab #13
A Collision in Two Dimensions *(continued)*

Name: ____________________

Date: ____________________

Figure 13



8. Now move the support at the lower end of the ramp so that the moving ball will hit a ball placed on the support. Put a ball on the support and roll the other ball down the ramp and observe the collisions. You do not want a collision where the moving ball barely hits the stationary ball or a head-on collision. Both balls should also move horizontally initially after the collision.
9. Once you have the balls colliding properly, tape a piece of paper to where each ball lands. Put carbon paper on top of each piece of paper. Have the balls collide five times, each time hitting their respective papers.
10. Remove the carbon paper and measure the distance to each dot. Record these data.
11. On the paper under the ramp, draw a line from the *X* toward each of the two clusters of dots. Find the angle between the line you drew toward each cluster and the line to where the single ball landed when it did not collide.
12. Finally, measure the height of the ramp above the floor.
13. Remove your pieces of paper from the floor and keep the one with the *X* and the angles on it.

(continued)

Name: ______________________________

Date: ______________________________

Cautions

1. Make sure that the balls move horizontally after leaving the ramp.
2. Do not remove your pieces of paper taped to the floor until you have all the proper measurements.

Analysis

1. Find the average distance that each set of black marks was from the position right under the ramp. Give some estimate of the error in this value.
2. Using the height of the ramp above the floor, find the time for the ball to fall from the ramp to the floor. Assume that the vertical velocity is initially zero.
3. Each ball moved horizontally the distance you found in step 1 in the time you found in step 2. Calculate each ball's velocity when it left the ramp. For the two balls which collided, give the angle at which they went. Write these on the piece of paper with the angles and the X on it.
4. Turn the paper so that the velocity vector for the ball which did not hit another ball is pointed to the top of the page. Call this the Y direction. At right angles to this direction is the X direction just as on a graph.
5. Find the X and Y components of velocity for each ball which collided. Make sure that you label them.
6. Multiply each of these velocities by m to find the momentum of each ball. (The actual mass does not matter because the mass of each ball is the same.)
7. Add together the momentum in the Y direction for the colliding balls.
8. Add together the momentum in the X direction for the colliding balls but remember that if they are in opposite directions, then you must use a negative sign for one value.
9. Next calculate the kinetic energy ($KE = (1/2)mv^2$) of each ball.
10. Add together the kinetic energy of the two colliding balls.

(continued)

Lab #13

A Collision in Two Dimension *(continued)*

Name: ______________________________

Date: ______________________________

Conclusions

1. The momentum you found for the ball that did not collide is equal to the momentum before the collision. The sum of the momenta of the two balls in the *Y* direction should equal this if momentum is going to be conserved. Is momentum conserved in the *Y* direction? Is the difference significant, given your measurement errors?
2. Before the collision, the moving ball had no momentum in the *X* direction so there should be no momentum after the collision. Was there any momentum in the *X* direction after the collision? Does your error associated with measurement error explain the differences?
3. Was the collision elastic, given your measurement errors?

Quiz #13
A Collision in Two Dimensions

Name: ______________________

Date: ______________________

1. When a projectile is fired horizontally across a level surface, it will stay in the air as long as
   a. an object thrown up at the same velocity.
   b. an object thrown down at the same velocity.
   c. an object fired horizontally with half the velocity from the same height.
   d. an object dropped from a height a little bit lower than the projectile was fired.

2. If an object flies horizontally off the end of a ramp and goes 4 meters horizontally in .5 sec, its horizontal velocity in m/sec is
   a. 1.
   b. 2.
   c. 4.
   d. 8.

3. Momentum is the product of
   a. velocity and displacement.
   b. velocity and force.
   c. force and displacement.
   d. velocity and mass.

4. In an elastic collision which of the following should be conserved?
   a. momentum
   b. energy
   c. momentum and energy
   d. neither momentum nor energy

5. A moving ball hits a stationary ball. Initially, the moving ball is going in the *Y* direction (at right angles to the *X* direction). After the collision, the momentum in the *X* direction should equal
   a. zero.
   b. the momentum in the *Y* direction.
   c. a value between zero and the momentum in the *Y* direction.
   d. It can't be determined with the given information.

Lab #13: A Collision in Two Dimensions

Teacher Notes

Cautions

1. Make sure that the balls move horizontally after leaving the ramp.
2. Do not remove your pieces of paper taped to the floor until you have all the proper measurements.

This is a long and involved lab but it does show conservation of momentum and energy in a two-dimensional collision. The error can be as much as 20% or more, however, so be prepared! The calculations and collection of data are quite involved and students must work fast if they only have one period to collect data. With two periods few students will finish the calculations. The lab is good as long as the students don't get lost along the way. If it overwhelms them, it may not be worth the effort.

The "collision in two dimension" apparatus is available from some supply houses and costs \$15–\$20. It can be used for this lab and a lab using projectiles sent horizontally off the ramp. The apparatus is simple and works relatively well. The height of the support for the stationary ball is critical. After the collision, both balls must be moving horizontally. In order to have this happen, their centers must be at the same height. This may require careful adjustment.

A similar lab can be done on an air table using a strobe photo. It is easier to do although getting enough pictures for each lab group can be trying if you have a large number of students. You can take the photographs beforehand and take one sample photo with the students present so they know how you got the photographs. This is preferable to the ramp experiment but the apparatus is much more expensive. The lab is analyzed in much the same way so this write-up can be modified to be used with the air table experiment.

Possible Problems

1. If the students move their paper before they have taken their measurements, they lose their data.
2. Some students will need to be guided through the calculations or they will become frustrated.
3. The idea that the momentum in the direction at right angles to the initial motion should be zero after the collision may baffle some students. It is almost too

(continued)

obvious for some to see. Also, at that stage in the calculations, some students may be frustrated with the lab and they will not appreciate the fact that zero is the correct answer.

Conclusions

1. The momentum in the *Y* direction equals the mass, *m*, times the velocity when the ball does not collide. The sum of the momenta in the *Y* direction after collision should equal this, too. There will be error, perhaps 20% or more in some cases.
2. The momentum in the *X* direction should equal zero because there was no velocity in this direction before the collision. The sum of the momenta in the *X* direction after collision should equal zero, too. There will be error of similar numerical size to the error in the *Y* momentum.
3. Kinetic energy should be conserved although some error will exist. Therefore, it should be an elastic collision.

LAB QUIZ ANSWERS

1. c
2. d
3. d
4. c
5. a