Collisions Of Elastic Spheres

This lab studies the collision between two spheres. The data you obtain from your measurements will be used to verify momentum conservation. This experiment will require efficient organization of a lot of data. You will use the spreadsheet program Excel to help you organize and analyze all your data.

Apparatus

Inclined ramp to propel incident sphere with a known velocity, supporting device for the target sphere, two steel spheres, two glass spheres, paper and carbon paper for locating position of spheres when they hit the floor, plumb bob to locate position of incident sphere before collision, clamps, balance, support rods, and string.

Objectives

In this experiment we want to study the collision of a moving sphere with a stationary sphere and examine the concepts of conservation of energy and momentum in such a process. You are to do all three parts of the experiment. It may be best to get data for all three parts before going into detailed analysis of one part. You may also want to find a way to divide up the analysis. In either case, come prepared and plan your lab time well.

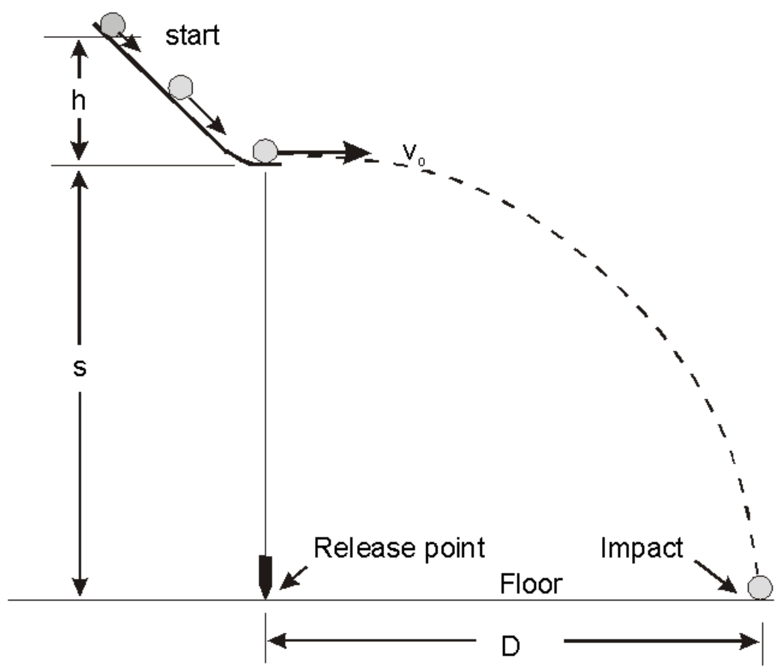


Figure 1

Procedure

Part I: Determination of the Initial Momentum

We will give an initial velocity to a ball by letting it roll down a ramp from a fixed height h. We locate the point below which it leaves the ramp and begins to fall, using a plumb bob and mark it on the floor. We record the point where the ball hits the ground by placing carbon paper on the white paper where the original impact occurs (so that the carbon paper will leave a mark on the white paper).

Obtain three successive impact points by repeatedly releasing the sphere from the same initial position, h. The three points of impact may show a little scatter. Identify the center of the points of impact by drawing the smallest circle that will contain all three of them. The radius of the circle used gives an estimate for the uncertainty in the position of the impact point.

Measure the fixed height h and the height s which the ball falls through. Analyze the motion of the ball after it leaves the ramp to find the relationship between V_0, the sphere's horizontal velocity as it leaves the ramp, and D, the point where the object lands (see Figure 1). Using this relationship and the measured distance D, find V_0. Also find the uncertainty in V_0. Compare this value of V_0 to what you would predict if V_0 is calculated from conservation of energy of the ball coming down the ramp. Discuss any discrepancies you observe. Measure the mass of the ball. From the measured mass and velocity, determine the ball's linear momentum.

Part II: Collisions between Equal Mass Balls

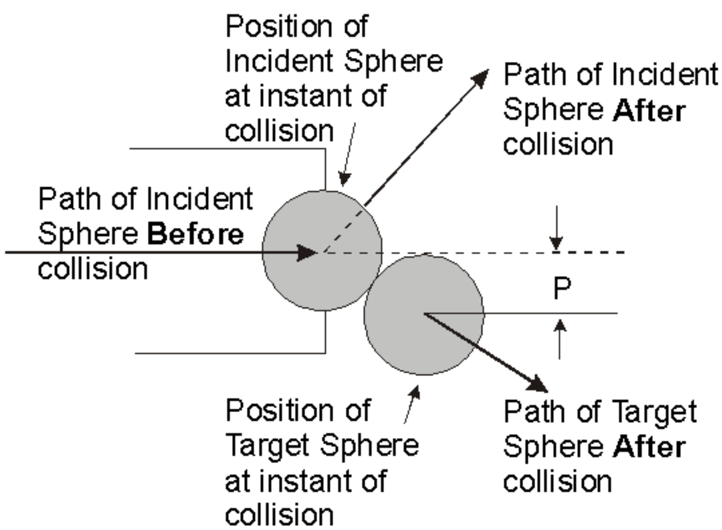


Figure 2

In this part we will investigate collisions between spheres of equal size and mass. To do so, we will place a target sphere on the support screw at the base of the ramp. The height of this screw should be adjusted so that the incident or projectile sphere will just pass over the screw without touching it when no target sphere is supported on it. Why? The position of this supporting screw can be moved sideways to vary the impact parameter of the collision. (Impact parameter is a measure of how far off center the collision takes place. It is equal to the distance P in Fig. 2.)

Perform a number of collision experiments for different impact parameters, always using the same value of h to release the incident ball. Record the landing points using carbon paper on the same sheet of paper which you

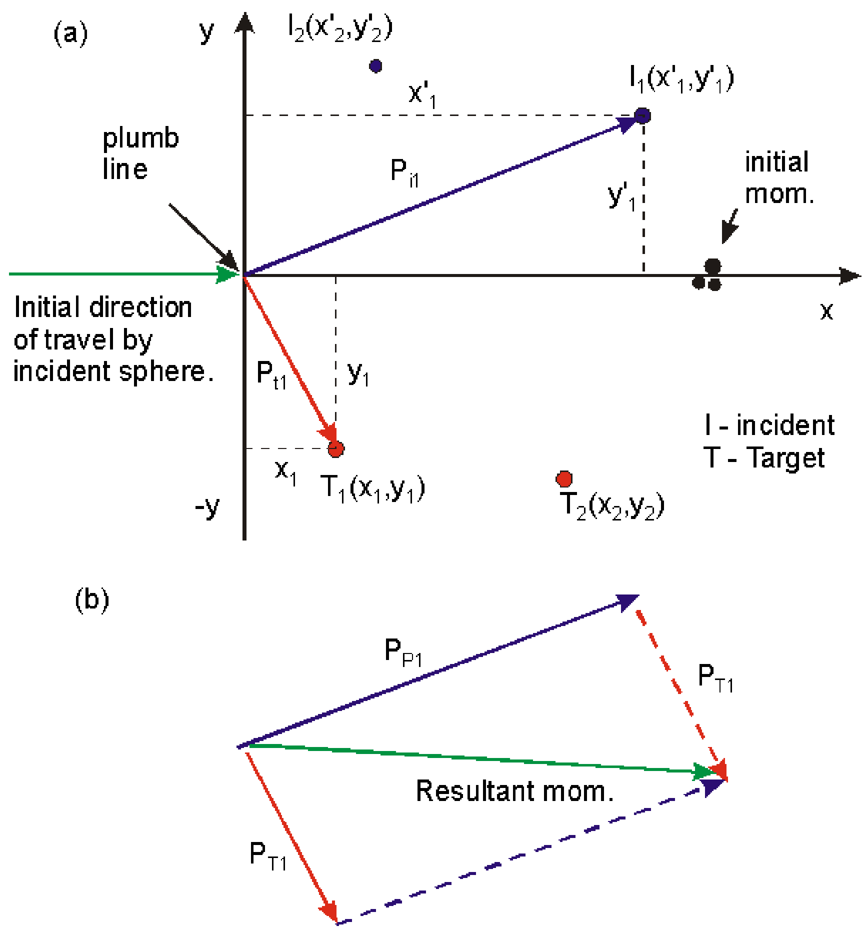


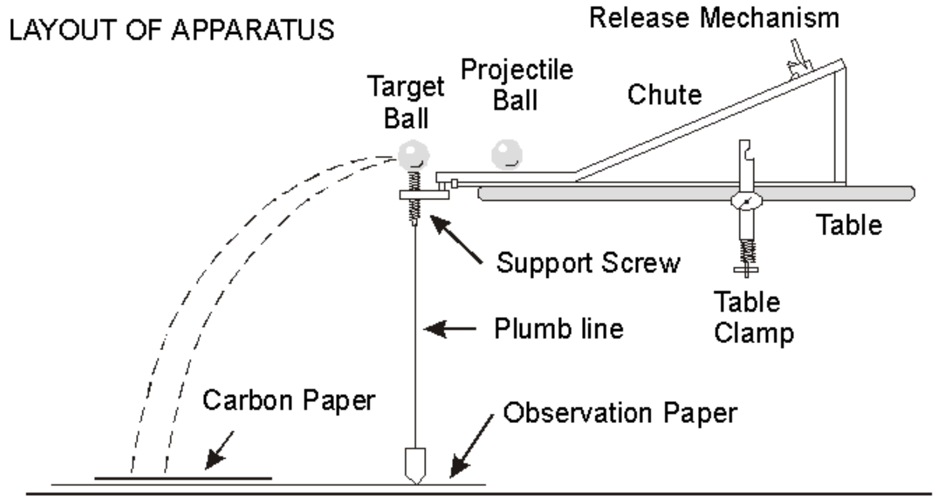
Figure 3

As you do this remember to

- Label corresponding landing points (get three points for each impact parameter) as they appear so that you can identify them by collision and by which ball made them.

- Adjust the position of the supporting screw for each new impact parameter so that the incident sphere makes contact in the same position when it leaves the ramp.

To know the correct velocity vectors you must know the position of each of the two balls at the moment of impact. The plumb bob indicates the position of the target ball at the moment of collision. The position of the incident ball may be found by following Fig. 2. If you should decide to ignore the differences in position or to use some other approximation, justify your action in terms of the uncertainties involved.



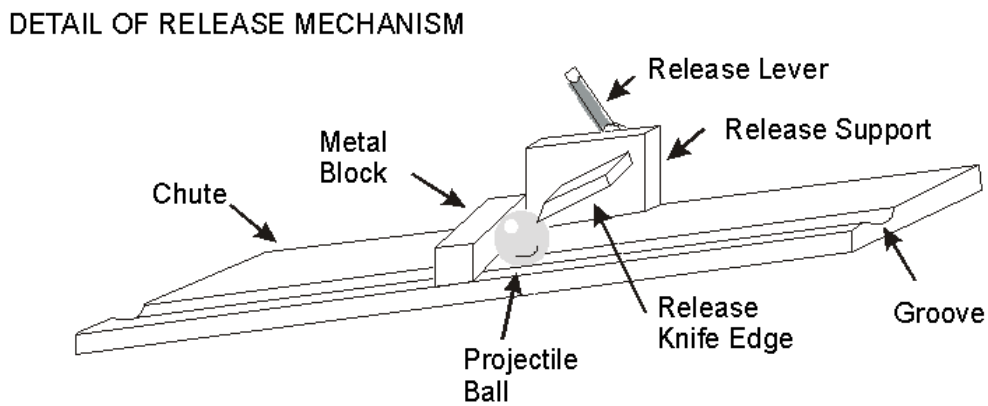


Figure 4

For one of the data pairs (i.e., the landing points of the two balls) draw the momentum vectors after the collision and compare them with the momentum vector before the collision.

Do your data indicate that, within experimental uncertainties, both energy and momentum are conserved for these collisions? If not, explain any discrepancies.

Part III: Collisions between Unequal Mass Balls

In this part we will investigate collisions between spheres of equal size, but unequal masses. The mass of the steel sphere, M, is obviously larger than that of the glass sphere, m. Which one should you use as the incident sphere? Follow the same procedure as in Part II. Record the landing positions of the two spheres after collisions with different impact parameters. To avoid confusion, **use a new sheet of paper to record your data**. Be sure to label the landing points after each experiment and record the point at which the impact spheres leave the ramp. Determine the masses of the two spheres you are using with a balance and record for later use. Whenever you take data be sure to record the uncertainty in your measurements. For example, in doing the collision experiments you should repeat the experiment three times for the same impact parameters to see how much your landing points scatter.

Is momentum conserved within the experimental uncertainty of your measurement? Explain. Make a similar computation for the energies of the spheres before and after collisions. To what extent is energy conserved?

Computations and Data Analysis

Use **Excel to record all data and to calculate the required quantities.** Make sure the data columns and single data entries are properly labeled and have their units indicated.

Enter your name and your partners' names at the top of the sheet. Identify if this data sheet is for *Collisions Between Equal Mass Balls* or *Collisions Between Unequal Mass Balls*.

A. Enter the preliminary data

1. Enter the height *s* of the launching point above the floor, the height *h* of the starting point on the ramp above the launching point, the mass *m1* of the incident ball, and mass *m2* of the target ball.
2. Enter the estimated uncertainties in these quantities.

B. Calculate the initial velocity, momentum and kinetic energy of the incident ball

1. Enter the value the measured value of D (see Figure 1). Enter the estimated uncertainty in the value of D.
2. Now calculate the value of the initial velocity of the ball in two different ways: first, by using the height *s* of the support and the horizontal distance *D*, and second, by using the height *h* and conservation of energy. Using propagation of errors, also estimate the uncertainties in these values.
3. How well do these independent measurements of V_0 agree? Discuss any reasons you can think of for the differences. Be sure to use the value of V_0 determined using *D* in the subsequent analysis.
4. Calculate the momentum of the incident ball.
5. Calculate the kinetic energy of the ball as it is launched from the edge of the ramp.

C. Calculate the momentum of the incident and target balls after collisions

1. Measure and record the x and y components for the distances to each group of hits made for each impact parameter. For each impact parameter, enter two pairs of measured (x, y) values, i.e. one pair each for the incident and the target balls. You do not need to enter separate distances for each spot, just for each group of spots. **The x-axis is the direction the ball goes if there is no target. The y-axis is perpendicular to that.** Enter y-values that are in the positive y-direction as positive and y-values in the negative y-direction as negative. Make sure you record the data for each ball consistently with their masses (keeping track of the subscripts 1 for incident and 2 for target).
2. Calculate the corresponding velocities by dividing each of the x and y distances by the time *t* it took to for the ball to drop from height *s* (and correspondingly, travel the horizontal distance D).

3. In four columns, compute the components of momentum, P_{x1}, P_{y1}, P_{x2}, and P_{y2} for each ball (incident and target).
4. Also, measure the angles *theta1* and *theta2* made by the paths of the incident and target balls with respect to the x-axis. Record *theta1* and *theta2* using two separate columns.

D. Analyzing your results

1. Compute a column containing $P_{x1} + P_{x2}$ and compare the value with the initial momentum of the ball. Compute a column containing $P_{y1} - P_{y2}$. What do you expect for this column? How close did your data come?
2. The sum of the angles measured from the x-axis should be 90°. Compute a column containing *theta1* + *theta2*? How close did your data come?
3. Compute a column containing the total kinetic energy after the collision. If these were elastic collisions, the total kinetic energies after the collision should equal the kinetic energy before the collision. How close were your data?

Now repeat the Computation and Data Analysis for the unequal mass balls and record the data using another sheet. When finished, print out a copy of all your data and computations to hand in with your lab report.

Some physics hints

1. When the incident ball starts at rest and drops through a height h, it loses potential energy of the amount $U = mgh$, and gains kinetic energy of the amount $K = ½\, m\, V_0^2$.
2. When a ball drops through a vertical height s, starting with an initial horizontal velocity V, it will spend $t = sqrt(2s/g)$ seconds in the air, and will go a distance $D = V\, t$ in the horizontal direction.
3. The x- and y-distances you measure are therefore easily converted into x- and y-components of velocity (just divide Dx/t, etc), and multiplication by m then converts these velocity components into momentum components.