Physics

When Worlds Collide

Purpose & Hypothesis

This lab examines what happens when objects collide and then move off in various directions. **State a principle** we learned recently that always governs the interactions between the objects inside an isolated "system". **Hint:** something is the same before and after any interaction. This lab will test whether this principle is true.

Overview

We will use two steel balls of equal mass, one of which will roll down an incline and make a glancing collision with a second ball that rests on a support. We'll use a trick to determine the velocity of each ball after they collide: we'll let the balls drop to the floor where they'll strike a sheet of carbon paper and make a mark. The time it takes a ball to hit the floor after the collision depends **only** on how high the ball starts above the floor (i.e., no matter what its horizontal velocity is), and so this will always be the **same** amount of time. Therefore, the amount it travels horizontally during this **fixed** time (i.e., its horizontal displacement) is directly proportional to its horizontal velocity immediately after the collision ($\vec{d}_{horizontal} = \vec{v}_{horizontal}\Delta t$).

Procedure

1. One of the steel balls will roll down the ramp and then collide with another that will be sitting atop the **black support screw**. Fasten the ramp to the edge of your table with the clamp so that after colliding, both balls will fly **away** from the table and won't hit anything else before they reach the floor. The **target support arm** that the black support screw is threaded into rotates from side to side (some move more easily than others), so make sure the big mounting plate extends far enough from the table (and the clamp doesn't get in the way) so that this **arm can move freely**.
2. Place one of the steel balls (the **target** ball) in the depression at the top of the black support screw. Place the second steel ball (the **attack** ball) next to it at the lower end of the ramp. By moving the **black support screw** up or down (and retightening the nut), adjust the height of the target ball so that it matches the height of the attack ball. This will ensure that they'll be moving only horizontally (not vertically) immediately after they collide.
3. Construct a **plumb bob** by tying one end of the thread to the loop of the screw eye in your baggie. Loosely attach the other end of the thread to the bottom of the black support screw and adjust the length of the string so that the tip of the plumb bob rests about 1cm or so above the floor (no need to measure it).
4. **WARNING! From this point on, it's important to avoid bumping the table or twisting the ramp, as doing so will skew your results <u>dramatically</u>. Practice twisting the target support arm left and right <u>without</u> moving the ramp. If there's someone in your group who is particularly klutzy, keep a close eye on this person <u>at all times</u>!**
5. Construct a huge piece of graph paper by taping four pieces together into a 2 x 2 grid **without overlapping the edges**, but **only apply tape to the back side**. Lay the graph paper on the floor with the **taped side down**, and with the plumb bob directly above where the **long** seam running down the middle of your graph paper reaches the **near** edge of the graph paper. The ramp should now be set up to launch directly down the **long** seam in the middle of your graph paper. Tape the graph paper to the floor, but **maintain the ramp alignment and plumb bob position**. Write a small "**C**" (for collision) where the plumb bob is pointing (i.e., near where the long seam reaches the edge of the graph paper). Call your instructor over to check your setup.
6. Lay your four pieces of carbon paper on top of the four graph paper sheets **with the black carbon side facing down. DO NOT tape the carbon paper down!** It's **not** important to line it up perfectly with the graph paper, and it's completely OK if the **carbon** sheets move around during the experiment. You just need carbon paper covering the areas of the graph paper where the balls are striking.

7. For the first trial, we'll see how far the attack ball (the one rolling down the ramp) will travel **without** colliding with a target ball. **Without moving the ramp itself at all**, twist the target support arm to the side and remove the target ball from it. One group member, the **Attack Ball Releaser**, should hold the attack ball against the **silver** screw at the **top of the ramp**, and then simply release the attack ball **without pushing it down or giving it any spin**. Repeat this procedure 10 times. You should get a close pattern of marks on the graph paper (lift the carbon paper to check). Draw an X in the very center of the pattern of marks, and then write "**A-0**" next to it.
8. To investigate a collision between two steel balls, twist the target support arm slightly **left** of center (as you **face in the same direction the ball is moving** when it comes off the ramp), and place the target ball on the black support screw. The Attack Ball Releaser should hold the attack ball against the silver screw at the top of the ramp, and then release the attack ball exactly as before. (Adjust the target support arm if both balls don't hit the carbon paper.) Repeat this procedure 10 times, **but make sure that the target support arm never moves between trials**. Draw an X in the very center of the pattern of marks made by the **attack** ball and write "**A-1**" next to it. Draw another X in the center of the marks made by the **target** ball and write "**T-1**" next to it.
9. Twist the target support arm to the other side of the ramp and repeat **Step #8** for this new position, labeling the attack ball marks "**A-2**" and the target ball marks "**T-2**".
10. Remove the carbon paper and draw a vector from the collision area to where the single ball (no collision) struck the floor in **Step #7** (i.e., from **C** to **A-0**). **Measure** and record both the **x** and **y components** of this vector. Make the y direction parallel to the ramp, and if **A-0** is on the **left** side of the seam (again, as you face in the direction the ball was moving), make its x component **negative**; otherwise make it positive. To help remember this convention, write "negative" on the left side of the paper and "positive" on the right side of the paper. All of your y-components will be positive, since they're all pointing in the direction the ball comes off the ramp.
11. Draw another vector from the point below the black support screw to the point where the **attack** ball struck the floor in **Step #8** (i.e., from **C** to **A-1**). Draw another vector for the **target** ball (i.e., from **C** to **T-1**). Measure and record the x and y components of the **A-1** and **T-1** vectors. Don't forget the sign of each x-component!
12. Draw another vector from the point below the black support screw to the point where the **attack** ball struck the floor in **Step #9** (i.e., from **C** to **A-2**). Draw another vector for the **target** ball (i.e., from **C** to **T-2**). Measure and record the x and y components of the **A-2** and **T-2** vectors. Don't forget the sign of each x-component!
13. Make sure each group member has a complete copy of your data (i.e., **both** components of all 5 vectors). Each of you will need this information in order to draw scaled-down copies of all the vectors and then perform his/her own analysis (see below). **Don't discard your graph paper,** as you might need to rework your measurements later.

Analysis and Conclusions

A1. The vector **A-0** is the horizontal displacement of the attack ball when no collision takes place, but since this is directly proportional to the ball's horizontal velocity, the **A-0** vector could also represent the velocity of the attack ball before it collides with anything. However, we will instead choose yet another type of quantity for the **A-0** vector (and the other vectors) to represent, because this quantity (directly proportional to the velocity) will help you test the principle you stated before beginning the lab. What type of quantity should our vectors represent?

A2. Re-draw the **A-0**, **A-1**, **T-1**, **A-2**, and **T-2** vectors, carefully scaling the x and y components down to 1/2 of their original length so that they all fit on a single 8.5" x 11" sheet of paper (with point **C** at the center of its bottom edge). Get the component signs correct so that each scaled-down vector points in **precisely the same direction** as the original vector, but is **precisely** half as long.

A3. Add vectors **A-1** and **T-1** (using the analytical method) to produce a new vector, and label it **R-1**. What quantity does the **R-1** vector represent? How does the **R-1** vector compare with the **A-0** vector?

A4. Add vectors **A-2** and **T-2** (again using the analytical method) to produce a new vector, and label it **R-2**. What quantity does the **R-2** vector represent? How does the **R-2** vector compare with the **A-0** vector?

A5. Comment on how well your results support the principle you stated in your hypothesis. Was it important that the two steel balls have equal mass? Why or why not?

A6. Repeat the analysis you did in **Step #A3**, but this time just add the magnitudes of the **A-1** and **T-1** vectors (either measure or use the Pythagorean Theorem to calculate the magnitudes). Compare your vector addition results with your magnitude addition results, and comment on any differences between them.