Lab N: Momentum Conservation

Introduction

The behavior of any moving object may be completely described by the object's **momentum** and **kinetic energy**. Linear momentum in particular is a conserved quantity, thus allowing us to **predict** the motions of objects after events like collisions, where energy and momentum are transferred. We will follow the motions of colliding objects to address the following questions:

- Is linear **momentum** always conserved?
- Under what conditions is **kinetic energy** conserved?
- How do **colliding** objects move?

Pre-Lab Questions

1. What are the equations for linear momentum p and kinetic energy K? Please define the variables.

2. Please define concisely and in your own words the concept of *conservation*. Describe conservation of momentum and kinetic energy.

3. Briefly describe the difference between elastic and inelastic collisions and give an example of each. Describe these collisions in terms of the kinetic energy and momentum.

4. A moving object collides with and sticks to a stationary object. Do the combined objects move slower, faster or at the same speed as the original moving object?

5. What is the expected value of the ratio of the final and initial momenta, p_f/p_i?

Equipment

An **air track** minimizes friction in the experiment by creating a cushion of air between the moving **glider** and the track. All data will be obtained through the **Pasco interface** and recorded, plotted and analyzed on the **computer**.

Photogates record the passage of the glider. The flag on the glider breaks the beam of light in the photogate, triggering the timers in the computer (Figure 1).

You will record the **speed** of the gliders through photogates before and after collisions.

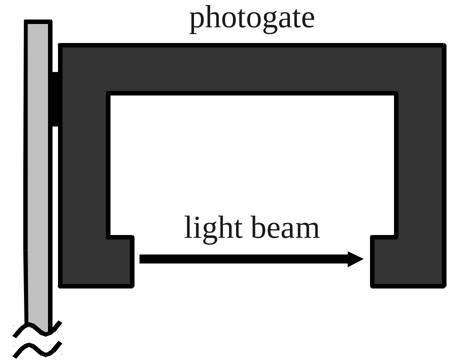

Figure 1.

Theory

The magnitude of an object's **linear momentum** depends on the object's **mass** and **velocity**, $\vec{p} = m\vec{v}$. As long as there are no external forces acting on a system, the total momentum is **conserved**, that is, it does not change with time. An object's **kinetic energy** also depends on its mass and speed, $K = ½ mv^2$.

You will find the momentum and kinetic energy by calculating the gliders' speeds through the two photogates.

Since the total momentum of a system is always **conserved**, the final and initial momentum should be equal. The kinetic energy is also conserved, but only for **elastic** collisions. If the gliders stick together – an **inelastic** collision – the kinetic energy will change because the mass of the moving object has changed. Figure 2 shows the first glider in motion towards the second, which is at rest. After an inelastic collision, the total mass will be M_1+M_2 moving at a new speed, v_f. Because of conservation of momentum:

$$M_1 v_i = (M_1 + M_2) v_f \,.$$

It should be obvious now how the pair of gliders move differently than the original glider alone (pre-lab question #4). The initial and final kinetic energy are then:

$$K_i = \tfrac{1}{2} M_1 v_i^2$$

$$K_f = \tfrac{1}{2} (M_1 + M_2) v_f^2$$

In an elastic collision, the total kinetic energy is conserved as well as the momentum, which, recall, is a **vector** quantity: $M_1 \vec{v}_{1i} = M_1 \vec{v}_{1f} + M_2 \vec{v}_2$.

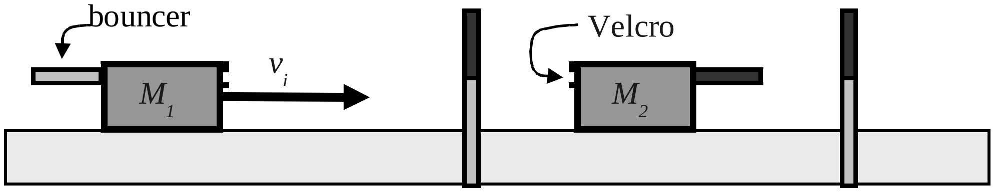

Figure 2.

Procedure

1. Measure the lengths (m) of the **flags** for the gliders twice.

2. Measure the masses (kg) of the gliders. The second glider should <u>not</u> have a flag.

3. Place the **gliders** as shown in Figure 2. Face the **Velcro** strips toward each other.

4. Turn on the Pasco interface box. Double-click on the **DataStudio** icon on the computer and choose **Create Experiment**.

5. Click on the first digital **channel port** in the image of the Pasco interface and choose the **photogate**. In the Measurements tab check "Time in Gate, Ch 1" and uncheck all others.

6. Click on the second channel port and choose photogate also. Check "Time in Gate, Ch 2" only and uncheck all others in both Measurement tabs.

7. Drag the "Time in Gate" lines in the upper left window to the **Table** line in the lower window. Both data sets should end up in Table 1.

8. Open a new Excel spreadsheet. Enter values for flag lengths (m), and the masses (kg). Make **column headings** for Run #, dt (s), and v (m/s).

9. Turn on the **fan motor** and wait a few seconds for the air flow to stabilize. Make sure the track is level. Click **Start** and *then gently* move the first glider towards the second, which is at rest. Do not let the gliders bounce back through the second gate. Click **Stop** and put the gliders back at their original positions. Once more, click Start and *then* release the glider.

10. Add **weights** to the second glider and measure the glider's new mass. Record the mass (kg) in the spreadsheet. Repeat #9.

11. Turn the gliders around so that the Velcro is no longer in the way and the bouncers face each other. Insert the **flag** into the second glider. Repeat #9. You should allow the first glider to return through the first gate.

Analysis

1. In the spreadsheet, calculate the **speed** of the gliders through the gates using the flag lengths and elapsed time in the gates. Review your results; how should the speeds change, if at all, as a result of the collisions?

2. In the spreadsheet, calculate the **momentum** and **kinetic energy** of the gliders before and after the collisions. Review your results; how should p and K change, if at all, after the collisions?

3. Calculate the average values of p_f/p_i and K_f/K_i. Review the results; what are the expected ratios? Calculate the percentage errors in your values.

Please save your spreadsheet on the computer. Print the spreadsheet or save it to an external drive to turn in to the instructor.

Questions

Please answer on a separate sheet.

1. Is **momentum** conserved in all of the experiments? Please give a complete description with examples as needed supporting your response.

2. Is **kinetic energy** conserved in all of the experiments? Please give a complete description with examples as needed supporting your response.

3. Does friction affect this experiment? If so, how? If not, why?

4. If the track were not perfectly level, how would your results change if at all?

5. How might this experiment be improved to illustrate better the concepts of conservation of momentum and kinetic energy?