Laboratory 11: Conservation of Momentum – Prelab

1 Inelastic collision

Two carts approach each other. One, with mass 690g travels right with speed 1.8m/s and the other with mass 550g travels left with speed 3.0m/s.

a) Determine the total momentum of the system of carts.

b) The carts stick and move together after colliding. In which direction will they move after the collision? Explain your answer.

2 Cart "explosion"

Two carts of different masses are initially held together and at rest. Cart 1 has mass m_1 and cart 2 has mass $m_2 = \frac{1}{2}m_1$. A spring release plunger on the carts triggered, causing the carts to move apart. How is the speed of cart 2 related to that of cart 1 after the plunger has been triggered? Explain your answer.

Laboratory 11: Conservation of Momentum – Activity

The law of conservation of momentum states that, for a system of objects on which there is *no net external force,* the total momentum remains constant. The aim of this exercise is to investigate this for collisions between two carts as illustrated in Fig. 1.

The momentum of any single cart at a given instant is

$$\vec{\mathbf{p}} = m\vec{\mathbf{v}}$$

where m is the mass of the cart and $\vec{\mathbf{v}}$ is the velocity of the cart at the instant. The total momentum of the system at any instant is $\vec{\mathbf{p}}_{\text{total}} = \vec{\mathbf{p}}_{\text{A}} + \vec{\mathbf{p}}_{\text{B}}$ where $\vec{\mathbf{p}}_{\text{A}}$ is the momentum of cart A at that instant and $\vec{\mathbf{p}}_{\text{B}}$ is the momentum of cart B at the same instant. Conservation of momentum implies that $\vec{\mathbf{p}}_{\text{total before}} = \vec{\mathbf{p}}_{\text{total after}}$. This laboratory exercise aims to verify this fact.
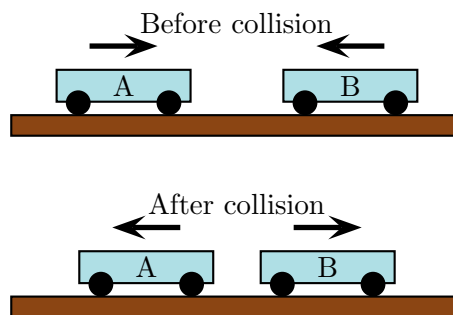

Figure 1: Colliding carts

1 Experimental Set Up

The carts can produce various "collisions" and each requires the following set up.

a) Level the track.

b) The velocities of the carts will be determined using photogates. Each photogate is interrupted by a black strip on the piece of plexiglass mounted on the cart. Capstone can measure the time taken for the black strip to pass through the photogate and convert this into information about the speed of the cart. Adjust the photogates so that the 5 cm black strip triggers the photogate and the two carts are able to collide after the strip has passed each photogate.

c) Open Capstone and connect each Photogate according to the instructions on page 7.

d) Drag a table into the Capstone display window. In one column select Velocity in Gate Ch 1 and in the other select Velocity in Gate Ch 2. For a collision in which the both carts pass through each gate twice, there will be four velocities. These are displayed in the relevant columns.

2 Elastic Collision

In an elastic collision the carts approach each other, collide and rebound as illustrated in Fig 2. To do this, orient the carts so that with the magnet ends facing each other.

a) Set up an elastic collision, with carts whose **masses are unequal**, and record the velocities for each cart *before and after* the collision.
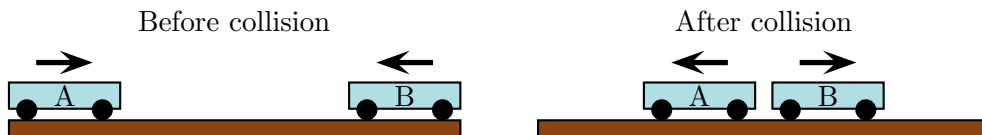
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Figure 2: Elastic collision

b) Calculate the horizontal (or x) component of the total momentum before and after the collision. Is momentum conserved?

c) A reasonable measure of the discrepancy between the momenta before and after the collision is

$$\text{Percent error} := \frac{p_{\text{total after}} - p_{\text{total before}}}{\text{Magnitude of largest } \textit{individual} \text{ momentum before}} 100$$

where $p_{\text{total before}}$ and $p_{\text{total after}}$ are the x-components of total momentum before and after the collision. Determine the percent error for this collision.

3 Inelastic Collision

In an inelastic collision involves carts that adhere as illustrated in Fig 3. To do this, orient the carts with the velcro ends facing each other.
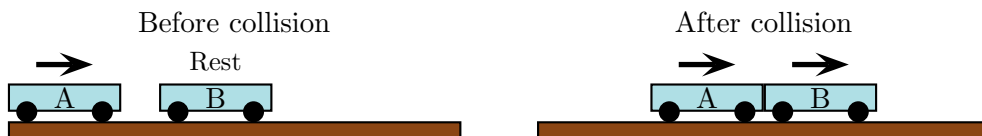

Figure 3: Inelastic collision

a) Set up an inelastic collision with the moving cart having about double the mass of the cart at rest. Determine the velocities *before and after* the collision.

b) Calculate the horizontal component of the total momentum before and after the collision. Is momentum conserved?

c) Determine the discrepancy between the momenta before and after the collision using

$$\text{Percent error} := \frac{p_{\text{total after}} - p_{\text{total before}}}{|p_{\text{total before}}|} 100.$$

4 Explosion

In an "explosion" both carts are held at rest against each other and the plunger is released as illustrated in Fig 4.

a) Set up an "explosion" and determine the the velocities *before and after* the event.

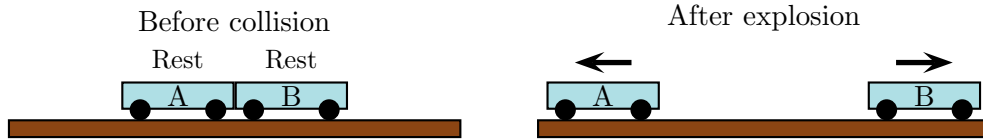b) Calculate the horizontal component of the total momentum before and after. Is momentum conserved?

Figure 4: "Explosion"

c) Determine the discrepancy between the momenta before and after the explosion using

$$\text{Percent error} := \frac{p_{\text{total after}} - p_{\text{total before}}}{\text{Magnitude of largest } \textit{individual} \text{ momentum after}} \, 100.$$

5 Conclusion

a) What do these experiments establish?

b) Explain any discrepancies between your observations and the theoretical predictions. For your explanation you should consider:

   i) How accurately you were able to measure the quantities needed to carry out the calculations.

   ii) Whether there were any "external" forces present that were excluded from the analysis.

6 Exercises

a) A cart with mass m_1 moving to the right collides with a cart with mass m_2 that is at rest. If m_2 is significantly larger than m_1 then several scenarios are possible. In one scenario the cart on the left rebounds as illustrated in Fig. 5.
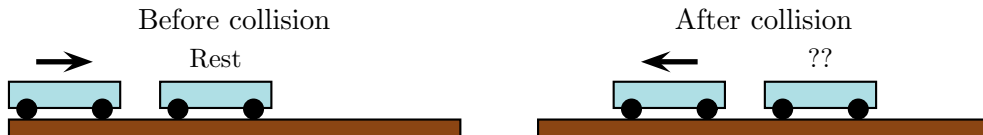

Figure 5: Rebound

In another scenario the cart on the left is at rest after the collision as illustrated in Fig. 6.
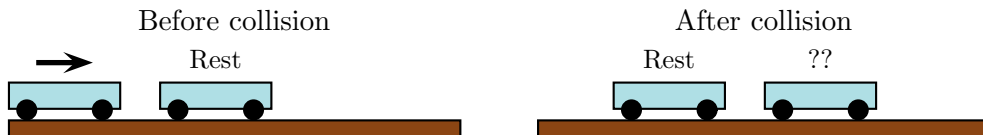

Figure 6: No rebound

In which scenario does the cart on the right move with greater velocity, assuming that the initial velocity of the cart on the left is the same? Explain your answer.

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b) Two carts with different masses are initially held together and at rest. One cart has mass m_1 and the other mass $m_2 = \frac{1}{2} m_1$. A spring release plunger on the carts triggered, causing the carts to move apart. Which cart moves with greater speed after the plunger has been triggered? Explain your answer.

c) Two carts are held together. The cart on the left has mass m_1 and that on the right mass $m_2 = \frac{1}{2} m_1$. They are set into motion so that their speed is $4\,\mathrm{m/s}$ to the right as illustrated in Fig 7.
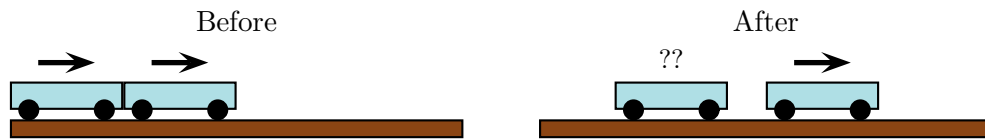

Figure 7: Carts initially together

After the plunger is triggered the cart on the right moves right with speed $6\,\mathrm{m/s}$. Determine the speed and direction of motion of the cart on the left after the plunger is triggered.

Setting up the photogate timer

Separately connect each Photogate in the interface icon. This will produce a Timer icon in the Tools palette. Click on the Timer icon and do as follows:

1. Select Pre-configured and click next.
2. Select Photogate Ch. 1 and click Photogate Ch. 2.
3. Select Collision (Single Flag) and click next.
4. Check the speed in gate 1 box and speed in gate 2 boxes and click next.
5. Use the default parameters and click next.
6. Provide a name and and click next.
7. Click finish.