4 Velocity of the Center of Mass of a System

Apparatus

Tracker video analysis software
Video: *collision-pucks.mov* from http://physics.highpoint.edu/∼atitus/videos/

Goal

The purpose of this experiment is to measure the velocity of the center of mass of two pucks that make a collision on an air hockey table. You will measure the center-of-mass velocity before the collision and after the collision, and you will compare the results.

Introduction

The location of the center of mass of a system of two particles is

$$\vec{r}_{cm} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2}{m_1 + m_2}$$

This is a vector equation that must be true for both the x and y directions (for two dimensions).

$$x_{cm} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2}$$

$$y_{cm} = \frac{m_1y_1 + m_2y_2}{m_1 + m_2}$$

Likewise, the center-of-mass velocity is

$$\vec{v}_{cm} = \frac{m_1\vec{v}_1 + m_2\vec{v}_2}{m_1 + m_2}$$

Again, this equation must hold true for both the x and y components of the center-of-mass velocity.

$$v_{cm,x} = \frac{m_1v_{1x} + m_2v_{2x}}{m_1 + m_2}$$

$$v_{cm,y} = \frac{m_1v_{1y} + m_2v_{2y}}{m_1 + m_2}$$

Procedure

It is expected that you have completed the other video analysis experiments, so these instructions do not include details about how to use the *Tracker* software.

1. Download the video *collision-pucks.mov* .
2. Open *Tracker* and insert the video.
3. Record the mass of each puck.

   $m_{blue} =$

   $m_{red} =$

4. Set the origin of your coordinate system.
5. Set the calibration using the meterstick on the left side of the video. You will have greater accuracy if you use 5 of the 10-cm segments for your calibration. In other words, stretch the calibration tool across 5 segments for a total length of 0.5 m.
6. Mark the blue puck for each frame of the video.
7. Mark the red puck for each frame of the video.
8. Using the graphs of x vs. t and y vs. t for each puck, measure the following quantities:

Table 4.1: default

	v_{xi}	v_{yi}	v_{xf}	v_{yf}
blue				
red				

Analysis

Calculate the x-component of the center-of-mass velocity *before* the collision, $v_{cm,ix}$.

Calculate the y-component of the center-of-mass velocity *before* the collision, $v_{cm,iy}$.

Calculate the x-component of the center-of-mass velocity *after* the collision, $v_{cm,fx}$.

Calculate the y-component of the center-of-mass velocity *after* the collision, $v_{cm,fy}$.

What is $\vec{v}_{cm,i}$? Write and sketch the vector.

What is $\vec{v}_{cm,f}$? Write and sketch the vector.

Tracker can track the center of mass for you. In the following steps, you will learn how to calculate the track the center of mass of the system.

1. We need to define the masses of the pucks. Click the tab for **mass A** in the Track Control toolbar. In the drop-down menu, select **Define...** . In the resulting pop-up window, enter the mass of the puck for the parameter **m** as shown in Figure 4.1.

2. Repeat the previous step for **mass B** and enter its mass.

3. Click the Create button and select **Center of Mass** , as shown in Figure 4.2.

4. You will see a new tab in the Track Control toolbar named **cm**. Click cm to get the menu for the cm object shown in Figure 4.3. Click the **Select Masses...** menu item.

5. An additional window will pop up. Select both masses "mass A" and "mass B" in this window and click OK as shown in Figure 4.4.

6. You will see a track for the center of mass and you will see a graph of x vs. t.

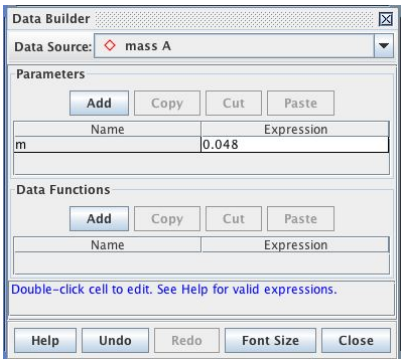

Figure 4.1: Enter of the mass of the puck.

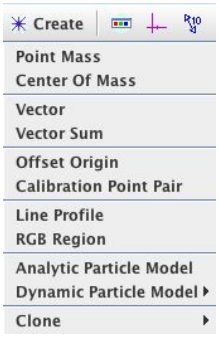

Figure 4.2: Select **Center of Mass** from the menu.

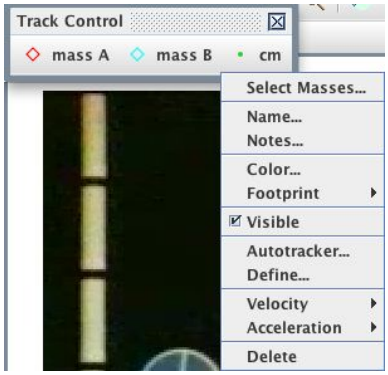

Figure 4.3: Click on **Select Masses...** from the menu.

By observing the *cm* track and by analyzing the graphs of $x(t)$ and $y(t)$, what can you say about the center-of-mass velocity? Is it constant or non-constant?

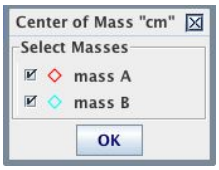

Figure 4.4: Check both masses (i.e. pucks) in this window.

Using the graphs of $x(t)$ and $y(t)$, measure $v_{cm,x}$ and $v_{cm,y}$.

Further Investigation

1. Is the center-of-mass velocity constant or non-constant?
2. What is the net force on the system of pucks?
3. The collision occurs in approximately 1/30 of a second. What is the force by the red puck on the blue puck during the collision?
4. What is the force by the blue puck on the red puck during the collision?