LAB A12v TESTING for CONSERVATION OF LINEAR MOMENTUM AND KINETIC ENERGY in an ELASTIC COLLISION

11/20/03

Goal

To test whether the laws of conservation of linear momentum and conservation of kinetic energy hold during a collision of two magnetic pucks on the air table.

Reading

Walker, section 7-2; Ch. 9 (particularly section 9-6); lab A14

Prelab

1. Do the electronic prelab problem if assigned by your instructor.
2. Even if you don't have do an electronic prelab, view the collision movies using the link on your web page or the link here: http://courses.ncssm.edu/physics/video/airtable2.htm
3. Prepare your lab books by transcribing the two tables (one for momentum and one for kinetic energy) found in this lab. (See tables on next pages or click on the links to jump to the tables.)

Gathering the data and getting it into the graphing software

You will be gathering data using the Videopoint software. Then you will use the Graphical Analysis software to analyze the data. Instruction sheets will be provided in the lab area to collect Videopoint data and transfer the data to Graphical Analysis.

AFTER you have gathered the data and transferred it successfully to Graphical Analysis, follow the instructions below to interpret your data.

Interpretation of the Collision Data:

<u>Determination of the initial and final speeds of both pucks and the CM</u>

Using Graphical Analysis, look at a graph of y_H vs. time. (y_H represents the y-coordinate of the position of the heavy puck.) The graph should be linear before and after the collision when the net force on the puck (Remember lab A11.) is zero. During the collision, the graph curves markedly. The slopes of the initial and final linear portions will give the initial and final velocities (along the y-axis).

Before doing any fits, decide which puck position numbers are "before" the collision and which puck position numbers are "after" the collision. After deciding which set of puck positions is "before" and which is "after" from the y_H data, look at your other data sets to confirm the linearity of the puck positions for your choice of "before" and "after". Clearly write and label the sets of puck position numbers for before and after the collision in your lab book.

Then call the instructor or work service assistant over to approve your choices for puck position numbers before and after the collision. Only after approval may you begin to do linear fits to your data in order to find velocity components. In order to determine these velocity components, do the following:

1. Do a linear fit to the set of puck y-positions that represent "before" the collision for the heavy mass. Select by clicking and dragging over the portion of points you want to fit.

2. Record the slope of the fit in the appropriate place in a table like the one below. Transcribe the table below into your lab book and add the correct units. You should always use SI units.

Object	Mass	Initial				Final			
		Velocities		Momenta		Velocities		Momenta	
		v_x	v_y	p_x	p_y	v_x	v_y	p_x	p_y
Light									
Heavy									
Total	XXX	XXX	XXX			XXX	XXX		
CM									

3. Repeat steps 1 and 2 for the set of puck y-positions after the collision for the heavy mass. Since we will not be printing graphs in this lab, make sure that you transfer your calculated speeds correctly into the tables in your lab notebook..

4. Repeat steps 1-3 for a graph of x_H vs. time. (This graph may appear linear throughout. However, analyze it the same as the y_H vs time graph.)

5. Repeat steps 1-4 for the light puck and then again for the center of mass.

6. Do your speed values make sense? Remember that you have pushed pucks on an air table recently. THINK about this now.

That's it for using the Graphical Analysis program to analyze data. Save your file before closing it.

Testing for conservation of x and y-momenta

Each partner must perform the following calculations independently. Partners should compare answers only after independent calculations. This procedure will help prevent calculation blunders. Record values in the same table in which you've already recorded velocity components. Be sure to answer all questions. (m_H = 0.338 kg and m_L = 0.187 kg)

1. Using the velocity components together with the masses of the pucks, calculate the initial and final x-momentum and the initial and final y-momentum of each puck. Use these values to determine total values of initial and final p_x and p_y.
2. Calculate the initial and final x-momentum and the initial and final y-momentum of the center of mass.
3. How close are the total initial and final x-momenta (% difference)?
4. How close are the total initial and final y-momenta?
5. How closely does the x-momentum of the CM match the x-momentum determined by summing the x-momenta of the two masses? Should these values match? why? (and same questions for the y-momentum)
6. List all the forces that operated on the masses during this experiment. Which forces could not have changed the system's momentum? Why? Which forces could have changed the system's momentum? Why?
7. If you were to examine your collision from lab A11, should you find that x- and y-momenta were conserved? Why or why not?

Testing for conservation of kinetic energy

As for the momentum calculations, each partner should work independently; the results should then be compared. Be sure to answer all questions.

8. Use the initial and final velocity components of the two pucks to determine their initial and final speeds. Enter your results in a table like the one below. Transcribe it into your lab journal and add the correct units.

Object	Mass	Initial				Final			
		v_x	v_y	v	KE	v_x	v_y	v	KE
Light									
Heavy									
Total	XXX	XXX	XXX	XXX		XXX	XXX	XXX	

9. Calculate the kinetic energies of each puck and enter them in the table. Then determine the initial and final kinetic energies of the two-puck system.

10. Why didn't we calculate x- and y-component kinetic energies in this part as we did with momentum in the previous part?

11. To what extent (i.e., percent difference) was kinetic energy conserved? Should kinetic energy actually have been conserved in this collision? Why or why not? If you were to examine your collision from lab A11, should you find that kinetic energy was conserved? Why or why not?

COLLECTING A12 DATA WITH VIDEOPOINT

Take heed! The key to success in this lab is following *these* instructions!

In the Videopoint instructions that follow, the questions to answer and the data to record are underlined.

Write your responses in your lab book ***and be sure to label them with the given number and letter of the question.*** Also label each section of your book using the same titles as in these instructions, e.g., "Collecting Data with Videopoint".

1. finding the movie data ……….

You will analyze an elastic collision of two magnetic pucks of unequal mass. The collision occurs on a level air table like the one you used for inelastic collisions in Lab A11. Video clips have been made of a number of collisions, and you'll be assigned one of them to analyze using Videopoint and Graphical Analysis. Ask your instructor which of the clips to download at this site:

http://courses.ncssm.edu/physics/video/airtable2.htm or http://phywww1.ncssm.edu/physics/video/airtable2.htm

Open a browser window now and access the above page. **DO NOT try to OPEN the clips here!**

Your teacher will assign partners a video clip to analyze. These might be labeled, for example, Now do the following to get started with your recording.

a) Record your lab partner's name.
b) Record the letter of your computer. (Look on the front of the monitor.)
c) Record the complete filename of the clip that you were assigned.
d) Why is it important that neither the table nor the camera moved during the clips that you will be analyzing?

2. Getting the movie clip…………

To get a movie clip, ***right click*** on the link, and use **Save Target As**… to save the clip to **your** M: drive.

[You might create a separate directory (called airtable) in which you store all of your A12 related data.]

3. Opening the movie clip in Videopoint…………

Once your movie clip has been saved, open the Videopoint software (click on Start, then mouse over Programs, Videopoint 2.1). Close the About Videopoint dialog box that comes up. You'll see the introduction screen, which will ask you what you want to do. Click on the **Open Movie** button.

Find the movie clip's location on your M drive and select the movie file to open the movie.

There will be a question asking how many objects you wish to follow on the movie. Select 2 objects and click **OK**. The movie will appear in the main program window together with a **Table** window and a **Coordinate System** window.

4. Viewing the movie clip…………….

View the movie by pushing the play button on the left of the bar at the bottom of the movie window (it looks like a play button on a tape recorder). You may see the pucks initially pushed on the table or the pucks might be free of the experimenter's hands in the first frame. Note that the pucks never touch. The pucks are magnetic, having like poles facing each other. Hence, they repel each other. The pucks are of unequal mass, the heavier one being on the bottom. It has been weighted with lead.

Why shouldn't you actually use a frame in which the hand was in contact with either puck?

How can you tell from watching the movie which puck is heavy and which is light? Explain.

5. Getting started on position data from the movie clip……….

Rewind the movie by dragging the slider at the bottom of the window all the way back to the left. Grab the lower right-hand corner of the movie window with the mouse pointer and drag the window open to maximize its size to increase precision in marking the puck positions. As you move the mouse around, you'll see a pointer on the screen labeled *Point S1*. Center this pointer over the initial position of light puck. The portion of the puck that you use is important. We recommend that you use the *base* of the puck handle rather than the top of the handle. In fact, there's a bright metallic circle at the center of the light puck, and you can center *Point S1* in this circle. Position *Point S1* within this circle as precisely as possible. Then, holding the mouse as steady as possible, single-click the left mouse button to enter the S1 coordinates in the data table. Note that cursor, S2, has appeared. Center S2 on the heavy puck (there is likely no metallic circle that you can see on this puck) and click to record the S2 coordinates. After you've clicked both pucks, the movie automatically advances to the next frame and S1 reappears.

6. Viewing the data table for the clip………..

The coordinates of the first data point for each puck should have appeared in the data table. In order to view the table, click on **View** in the main menu bar and then select **Data Table**. This will bring the table to the front. Note that the (x,y) coordinates are given in pixels relative to the coordinate axis shown on the movie window. Later, you will scale these measurements to meters and reposition the coordinate origin. Note also the sequence of times. These are the actual times for sequential frames. If, for example, your clip was taken at 30.0 frames per second, the times would increase in $1/30^{th}$ second intervals.

What is the time interval between frames for your clip?

7. Completing the data table…………

Click once on the Videopoint title bar or on the movie window to bring the movie back into the foreground. You should be on frame 2 of the clip. (This is indicated in the upper right-hand corner together with the total number of frames.) *Point S1* should be visible again. Center it on the light puck and click. Now *Point S2* should be visible again. Center it on the heavy puck and click. This will advance you to frame 3. Be very careful to not mix up the *S1* and *S2* points, as this will seriously mess us your data analysis! If at any time you need to change the coordinates for a point because you clicked on it wrong, do the following:

a) Use the frame-by-frame buttons below the movie until you are at the frame and puck for which you want to change your data. *Point S1* or *Point S2* should be visible on the movie. Highlight the point that needs correcting.
b) On the main menu bar at the top of the screen, click **Edit, Clear Selection on Frame**. The coordinates for that frame will be deleted from the data table.
c) Reposition *Point S1* or S2 to the center of the puck and click. The new coordinates will be entered in the table.

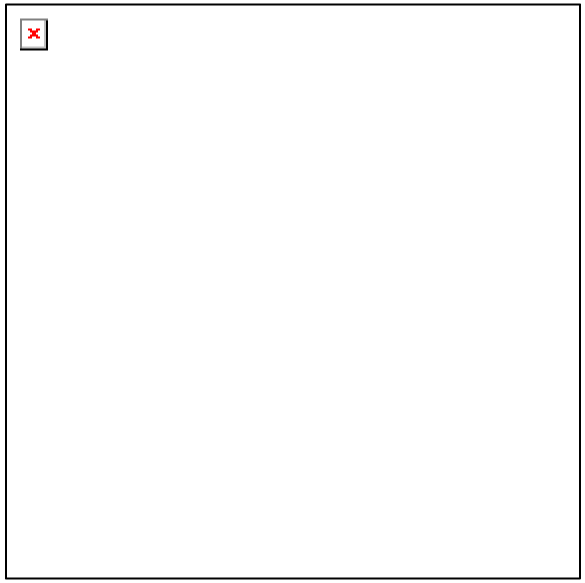
Continue to click on the centers of the pucks for all valid the frames of the movie. Remember, you don't want any frames where the puck is being touched by a hand or the edge of the airtable.

8. Checking your data points…………

When you're done collecting the data points, highlight the points for one of the frames and then press Ctrl-T. This will show you a trail of the points that you clicked, each point being indicated by a crosshair. If you want to check any of them, use the frame-by-frame buttons to move to the frame of interest. Then you can see how well your marked points match up with center of the puck. If you need to change any points, use the procedure described in 7a)-c) above.

9. Plotting the center of mass………..

In Lab A11, you plotted the center of mass of a system of two equal mass pucks. In this lab, the pucks are of unequal mass (m_H = 0.338 kg and m_L = 0.187 kg), but the method is similar. If, for example, the position of the heavier puck is taken as $x_H = 0$, the x-coordinate of the center of mass is:



Videopoint will plot the center of mass points for you. Use the following procedure.

a) Single click on Point S1 in the Coordinate System window.
b) From the main menu bar, select Edit, Edit Selected Series.
c) In the dialogue box that appears, enter the mass of the S1 puck. Be sure that the units match the number. Then click on OK.
d) Repeat steps a-c for Point S2.
e) From the main menu, select Create, Center of Mass.
f) Click on Point S1, then Add >>. Repeat for Point S2.
g) Click on Leave Trails and then click on OK. The center of mass points should appear overlayed on the video.

10. Checking and saving the data table……….

View your data table once again. All of the data should now be entered. IMPORTANT: Videopoint, like all software, sometimes crashes, so it's a very good idea to save your data regularly to your M: drive. Do this now - on the main menu bar, select **File, Save As**. Give the file a unique name and be sure that "VPT (.VPT) files" is showing in the **Save As Type** box. Then click **OK.**

Record the filename in your data book.

11. Scaling the position data…………

Now it's time to scale your data in meters. First, you'll need to find two fixed and identifiable points on the air table between which you can measure a distance in meters. The ruler at the side of the video window can be used for scaling. The separation of like edges of adjacent black pieces of tape (see the ruler visible in the video) is 0.100 m. Use the largest known distance possible.

Now that you know the actual distance between the two points, you must enter that information into Videopoint so that the coordinates of your data points will be scaled in actual meters. Here's the procedure:

a) Select the movie window by clicking on its title bar. In the main menu bar, click on **Create.** In the Create menu, select **Point**. In the Data Type popup box, select **Fixed** instead of **Frame-by-Frame**. Click **OK**. This creates *Point S3* and will define one endpoint of your distance scale. Place the cursor on one of the two fixed points that you identified. Click to record the coordinates.
b) Repeat step a) for your second fixed point. This will create *Point S4*.
c) Once again, select **Create** but this time click on **Scale**. In the dialogue box, select **Point S3** and then click on **Add**. Repeat for **Point S4**. Then, in the **Length** box, type the actual distance (in meters) between the two points. Then click **OK**.

12. Setting the coordinate axes (i.e., the origin)………..

There's no need to move the x- and y-axes from their present locations. This selection is arbitrary!

13. Last data check before analysis…………….

Now your data table should have meaningful numbers. Look at the **Table** window to check this.

14. Save your final data………….

If you're satisfied with your results, it's time to save your data file once again. In the main menu, select **File, Save**. You won't have to give a filename this time, since you selected one before.

15. Delete the movie clip……………

At this point, you should no longer need the movie clip (a *.avi file) that you saved in your M: directory at the start. We suggest that you delete it now, since it takes up much disk space.

Be sure your partner also has a copy of the file! Don't lose all of your work!

TRANSFERRING THE A12 DATA TO GRAPHICAL ANALYSIS

Now you have the data you need to determine initial and final velocities of the pucks and the center of mass. Although Videopoint has analysis options, Graphical Analysis for Windows is much better for this. Here's the quickest way to transfer your data.

16. While still in Videopoint, go to the **Table** window. Click at the top of one of your seven data columns (time, light x-pos, light y-pos, etc.) under the S1 heading, then press the CTRL key on your keyboard, then click at the top of each of the other six data columns while holding the CTRL key down. All seven of the data columns should now be highlighted in black. Now release the mouse button and CTRL key and move the cursor to **Edit** on the main menu. Click on **Edit** followed by **Copy Data**. This copies all your data to the Windows clipboard.

17. Minimize the Videopoint window by clicking on the minimize button in the upper right corner. Then open Graphical Analysis by going to the Start button on your computer's menu bar, then choosing Graphical Analysis .

18. After Graphical Analysis loads, change the names of the two columns in the Graphical Analysis data table to **Time** and **light x** and give them correct units and significant figures. Then, on the main menu bar, select **Data, New Column, Manually-entered**. In the dialogue box that appears, type **light y** for the name and enter the units and significant figures. Create 4 more new, manually-entered columns and name them properly. Remember, you need a total of 7 columns for Time and x- and y-coordinates of the light puck, heavy puck, and the center of mass. *As you name the columns, compare to the data table in Videopoint, making sure that each column is correctly identified in the same order as the Videopoint table. A mistake at this point will invalidate all future results.*

19. Click on the title of the table: **Data Set**. On the main menu, select **Edit, Paste**. All your data from Videopoint should appear. If the column headings from the Videopoint table were transferred to Graphical Analysis, delete them. Before working further with the data, you should save it as a .dat file in your M: directory. On the main menu bar, select **File, Save As**. In the **Filename:** box, type the same name that you used for your Videopoint file with this exception: leave off the .vpt extension. Click **OK**. Graphical Analysis will automatically add the extension .ga3 to your filename. You can check this by looking at the title bar at the top of the screen.
    a) <u>Record the name of your .ga3 file.</u>
    b) <u>Save the file to your M drive and the M drive of your partner.</u>

LAB A12 Instructor/Assistant checkpoints during lab

Videopoint checkpoints

vp1. Have: lab partner name

computer letter

filename of movie

vp 2. Question: Why are frames with hand on puck bad? —we want a PHYSICS answer.

vp 3. Be sure S2 is the heavy puck. Question how they know which puck is heavy—we want a PHYSICS answer.

vp 6. Time interval? Be sure it is correct.

vp 8. Check puck tracks. Make them fix points if necessary.

vp 9. Check CM track. If grossly curved, check method carefully.

vp 10. Make sure file is saved!

vp 11. Be sure maximum known distance was used and used CORRECTLY (be sure LIKE tape edges were used left-left or right-right)

vp 12. Coordinate axes. Why are they arbitrary?

vp 13. Table check. How do they know the numbers are actually reasonable?

Graphing checkpoints

GA19. All seven data columns transferred are in correct order and correctly named with units.

Six printed graphs with two printed fits on each graph.

Checkpoint for data collection Lab A12 class block __________

partners	vp 1	vp 2	vp 3	vp 6	vp 8	vp 9	vp 10	vp 11	vp 12	vp 13	ga 19	6 graphs

Checkpoint for data collection Lab A12 class block __________

partners	vp 1	vp 2	vp 3	vp 6	vp 8	vp 9	vp 10	vp 11	vp 12	vp 13	ga 19	6 graphs