

## Experiment 5

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# Elastic Collisions

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### 5.1 Objectives

- Measure the momentum and kinetic energy of two objects before and after a (nearly) elastic one-dimensional collision.
- Try to account for any change in KE in the nearly elastic collision.
- Compare and contrast the results obtained from the inelastic collision experiment with the results obtained from this experiment.

### 5.2 Introduction

Now that we are acquainted with inelastic collisions, it is time to investigate elastic collisions. In an elastic collision, two or more bodies collide and then move apart with **no loss in kinetic energy**. So this week we will observe the conservation of momentum AND kinetic energy. Though we will not have ideal conditions (i.e. a perfectly frictionless system in a vacuum) we will be able to see these conservation laws with very good precision.

### 5.3 Key Concepts

You can find a summary on-line at Hyperphysics.<sup>1</sup> Look for keywords: elastic collision.

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<sup>1</sup><http://hyperphysics.phy-astr.gsu.edu/hbase/hph.html>

## 5.4 Theory

This section will only provide information that is relevant for elastic collisions and differs from last week's experiment. Please refer back to the Inelastic Collisions lab if you need more information on the theory of collisions.

This week we will try to obtain an (almost) elastic collision of two carts on an air track. The main difference from the previous lab is that the carts will now move separately after the collision. An elastic bumper allows the carts to bounce off of each other with almost no conversion of kinetic energy into other forms. Like last week, Cart #2 will initially be at rest ( $v_{2i} = 0$ ) and Cart #1 will have some initial velocity  $v_{1i}$ . After the collision the two carts will move separately with final velocities  $v_{1f}$  and  $v_{2f}$ . You will need the carts' masses and velocities to calculate the initial and final momenta and kinetic energies. This week you should find that both momentum and kinetic energy are conserved.

Remember that momentum,  $\vec{p}$ , is a **vector** quantity. In one dimension it has a sign. You will need to pick a coordinate system and define one direction to be positive and the opposite to be negative. Using conservation of momentum ( $\vec{p}_i = \vec{p}_f$ ) and the fact that Cart #2 is initially at rest gives:

$$m_1\vec{v}_{1i} = m_1\vec{v}_{1f} + m_2\vec{v}_{2f} \quad (5.1)$$

In an elastic collision kinetic energy is conserved so  $KE_i = KE_f$ . The equation for the initial kinetic energy is the same as last week but this time (as the two carts don't stick together) the final kinetic energy is given by:

$$KE_f = \frac{m_1v_{1f}^2}{2} + \frac{m_2v_{2f}^2}{2} \quad (5.2)$$

Like last week Cart #2 will initially be at rest ( $v_{2i} = 0$ ) so before the collision we have to measure only the velocity of Cart #1,  $v_{1i}$ . However, after the collision we have to measure the velocities of **both** carts,  $v_{1f}$  and  $v_{2f}$ . In total we have to measure three times ( $t_{1i}$ ,  $t_{1f}$  and  $t_{2f}$ ), while the photogate system only allows us to simultaneously measure two of them. We can get out of this situation if **after** the measurement of the initial time  $t_{1i}$ , but **before** the collision of the two carts, we reset the timer. You will probably need to make several practice trials to learn how to write down  $t_{1i}$  quickly and then reset the timer before the carts collide. After the collision you can use the contents of the timer display and its memory, like you did last week, to find  $t_{1f}$  and  $t_{2f}$ .

## 5.5 In today's lab

In today's lab, you will observe a (nearly) inelastic collision and check that both momentum and kinetic energy are conserved. You will vary the amount of mass on the two colliding carts and observe the effects on elastic collisions. You will compare the results of elastic collisions with those of inelastic collisions and try to understand where energy loss can occur.

## 5.6 Equipment

- Air Track
- Air Supply
- Two carts (one with a bumper and one with a blade, see Fig. 5.1)
- Photogate Circuit
- 4 - 50g masses

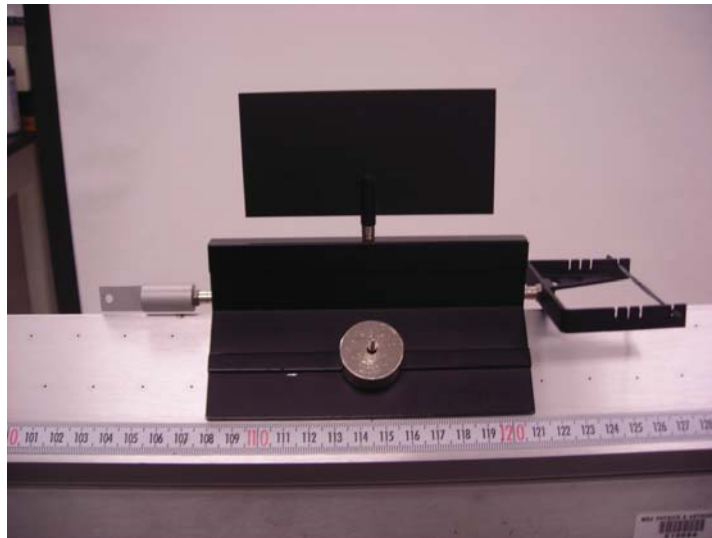


Figure 5.1: Cart with bumper.

## 5.7 Procedure

1. Start by making sure that the air track is level. Your instructor will demonstrate how at the beginning of class.
2. We will define Cart #1 as the cart with the **bumper** and Cart #2 as the cart with the **bumper blade**. For each trial, you will always push Cart #1 and have Cart #2 stationary ( $v_{2_i} = 0$  cm/s) in the middle between the photogates. Both carts will have fins on top.
3. Set up the photogates such that there is sufficient room to reset the timer before the collision happens. Make sure the fin on Cart #1 passes all the way through the first photogate before colliding with the second cart. You need enough room “outside” both photogates to allow the carts to move freely with their fins passing all the way through the photogates before hitting the end of the track.
4. Set the photogates to **GATE** mode and make sure the memory switch is set to ON.
5. Measure the mass of your carts. Make sure that the pegs are in the **bottom holes** on the carts. There should be a bumper on Cart #1 and a counter balance peg on the opposite side. Cart #2 should have a bumper blade and a counter balance peg on the other side. Both carts should have a fin on top. Measure the mass of each cart, including the pegs and fin but **without** the 50 g masses, and record it in the spreadsheet in the cells for the “Mass of empty cart” 1 and 2.
6. Measure the lengths of the fins on both carts (they should be the same) and record them in Excel. Be sure to put a reasonable uncertainty for the fin length.
7. Input the uncertainty for the times measured by the photogate into Excel. You will use an uncertainty of 0.0005 seconds.
8. Put 2 masses on Cart #2 so they are evenly distributed (1 on each side) and no masses on Cart #1.
9. Place Cart #2 in between the photogates and have one partner hold the cart steady until the collision occurs. Place Cart #1 “outside” of the photogates.

10. Making sure that your timer is reset to 0.0, give a brief but firm shove to Cart #1 such that it collides with Cart #2. Allow the two carts to leave the middle and pass through the photogates completely before stopping them. **Do not let the carts drift back through the photogates until you finish recording the times.** Be sure to have one partner memorize the first time that appears on the photogate ( $t_{1i}$ ) and reset the photogate **before either cart passes through the photogates after the collision.** It may take multiple tries to get this method correct, so feel free to practice a few times.
11. Record  $t_{1i}$  in Excel. Also record the other times off of the photogate in Excel. **If you reset the timer at the correct moment, the time you read on the photogate prior to flipping the READ switch will be either  $t_{1f}$  or  $t_{2f}$  depending on which cart left the middle first. The *other* time will be calculated the same way as last week using  $t_{mem}$ .**
12. Note that the velocities are calculated using  $L/t$ , same as last week, but you will need to make sure you enter the correct sign indicating which direction each cart was moving. (Remember velocity is a vector quantity.)
13. All other formulas have already been programmed into Excel for you. You must provide sample calculations (written out by hand on a separate piece of paper) for the cells shown in blue in the spreadsheet:  $\delta v_{1i}$ ,  $P_{1i}$ ,  $P_f$ ,  $\delta P_{1i}$ ,  $KE_{1i}$  and  $\delta KE_{1i}$ .
14. You will do a total of 6 trials with the following distribution of the 50 gram masses on the carts:
  - Trials 1 & 2: 0 mass disks on Cart #1, 2 mass disks on Cart #2
  - Trials 3 & 4: 2 mass disks on Cart #1, 2 mass disks on Cart #2
  - Trials 5 & 6: 2 mass disks on Cart #1, 0 mass disks on Cart #2

Make sure to keep the masses distributed symmetrically on the carts and to record the correct masses for  $m_1$  and  $m_2$  (including the mass disks) into the spreadsheet. For trials 3 and 4, you may use 1000s for  $t_{1f}$ . This is to approximate an infinite time as ideally Cart #1 will transfer all of its momentum to Cart #2 and stop moving after the collision (i.e.  $v_{1f} = 0$  and  $t_{1f} = \infty$ ).

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15. Make sure that the absolute value of the percent difference between initial and final momentum is less than 5% *AND* the absolute value of the percent difference between initial and final kinetic energy is **less than** 10% (the spreadsheet does these calculations for you) for all your trials. If they are not, rerun the trials. If you are having problems look back at the Inelastic Collisions lab for troubleshooting hints.
16. Be sure to include hand calculations for the light blue boxes in Excel.

### 5.8 Checklist

1. Excel spreadsheets (data and formula views)
2. Answers to the questions.
3. Hand calculations for the 6 highlighted cells.

## 5.9 Questions

1. For which of your trials was momentum conserved? Justify your response. Show a consistency check for at least one trial. If momentum was not conserved for any of your trials, describe possible sources of error.

2. For which of your runs was kinetic energy conserved? Justify your response. Show work for at least one trial. If kinetic energy was not conserved for any of your trials, describe possible sources of error.

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3. Describe how the elastic collisions changed as the distribution of the mass disks on the carts was changed. For example, discuss differences in the speed and direction of the carts or in the percent changes in momentum and kinetic energy for the 3 different mass configurations.

4. Compare your percent changes in momentum and kinetic energy for the inelastic collisions experiment with the elastic collisions experiment. Did your results agree with what was expected? What was conserved or not conserved?



	A	B	C	D	E	F	G	H	I	J	K	M
1	<b>Elastic one-dimensional collisions</b>											
2												
3	Partner:						Name:					
4												
5	Error in time (cell name: dt) "dt"						value units					
6	Length of fin ( cell name: L) "L"						[cm]					
7	Error in fin length (cell name: dL) "δL"						[cm]					
8	Mass of empty cart 1						[g]					
9	Mass of empty cart 2						[g]					
10	Error in time (cell name: dt) "dt"						[s]					
11	Use the specified "cell name" when using these variables in your calculations.											
12												
13	Measure quantities in			Calculate the others			Provide calcs for:					
14												
15	<b>Cart 1 Initial State</b>											
16	Trial	m <sub>1</sub>	t <sub>i</sub>	v <sub>1</sub>	δv <sub>1</sub>	p <sub>1</sub>	δp <sub>1</sub>	KE <sub>1</sub>	δKE <sub>1</sub>			
17		[gm]	[s]	[cm/s]	[cm/s]	[gm cm /s]	[gm cm/s]	[gm (cm/s) <sup>2</sup> ]	[gm (cm/s) <sup>2</sup> ]			
18	1				#DIV/0!		#DIV/0!		#DIV/0!			
19	2				#DIV/0!		#DIV/0!		#DIV/0!			
20	3				#DIV/0!		#DIV/0!		#DIV/0!			
21	4				#DIV/0!		#DIV/0!		#DIV/0!			
22	5				#DIV/0!		#DIV/0!		#DIV/0!			
23	6				#DIV/0!		#DIV/0!		#DIV/0!			
24												
25	<b>Cart 1 Final State</b>											
26	Trial	m <sub>1</sub>	t <sub>1f</sub>	v <sub>1f</sub>	δv <sub>1f</sub>	p <sub>1f</sub>	δp <sub>1f</sub>	KE <sub>1f</sub>	δKE <sub>1f</sub>			
27		[gm]	[s]	[cm/s]	[cm/s]	[gm cm /s]	[gm cm/s]	[gm (cm/s) <sup>2</sup> ]	[gm (cm/s) <sup>2</sup> ]			
28	1				#DIV/0!		#DIV/0!		#DIV/0!			
29	2				#DIV/0!		#DIV/0!		#DIV/0!			
30	3				#DIV/0!		#DIV/0!		#DIV/0!			
31	4				#DIV/0!		#DIV/0!		#DIV/0!			
32	5				#DIV/0!		#DIV/0!		#DIV/0!			
33	6				#DIV/0!		#DIV/0!		#DIV/0!			
34												
35	<b>Cart 2 Final State</b>											
36	Trial	m <sub>2</sub>	t <sub>2f</sub>	t <sub>mem</sub>	v <sub>2f</sub>	δv <sub>2f</sub>	p <sub>2f</sub>	δp <sub>2f</sub>	KE <sub>2f</sub>	δKE <sub>2f</sub>		
37		[gm]	[s]	[s]	[cm/s]	[cm/s]	[gm cm /s]	[gm cm/s]	[gm (cm/s) <sup>2</sup> ]	[gm (cm/s) <sup>2</sup> ]		
38	1					#DIV/0!		#DIV/0!		#DIV/0!		
39	2					#DIV/0!		#DIV/0!		#DIV/0!		
40	3					#DIV/0!		#DIV/0!		#DIV/0!		
41	4					#DIV/0!		#DIV/0!		#DIV/0!		
42	5					#DIV/0!		#DIV/0!		#DIV/0!		
43	6					#DIV/0!		#DIV/0!		#DIV/0!		
44												
45	Below enter the summary for the initial and final state momenta											
46	Do not copy/paste information in here, but use P <sub>i</sub> =(cell # for)p <sub>1</sub> , P <sub>f</sub> =p <sub>1f</sub> +p <sub>2f</sub> , etc											
47	% change = 100% * P <sub>diff</sub> /P <sub>i</sub>											
48	Trial	P <sub>i</sub>	δP <sub>i</sub>	P <sub>f</sub>	δP <sub>f</sub>	P <sub>diff</sub>	δ(P <sub>diff</sub> )	%				
49		[gm cm /s]	[gm cm /s]	[gm cm /s]	[gm cm /s]	[gm cm /s]	[gm cm /s]	change				
50	1		#DIV/0!		#DIV/0!		#DIV/0!	#DIV/0!				
51	2		#DIV/0!		#DIV/0!		#DIV/0!	#DIV/0!				
52	3		#DIV/0!		#DIV/0!		#DIV/0!	#DIV/0!				
53	4		#DIV/0!		#DIV/0!		#DIV/0!	#DIV/0!				
54	5		#DIV/0!		#DIV/0!		#DIV/0!	#DIV/0!				
55	6		#DIV/0!		#DIV/0!		#DIV/0!	#DIV/0!				
56												
57	Below enter the summary for the initial and final state KE											
58	Do not copy/paste information in here, but use KE <sub>i</sub> =KE <sub>1</sub> ,KE <sub>f</sub> =KE <sub>1f</sub> +KE <sub>2f</sub> ,etc											
59	% change is 100% * KE <sub>diff</sub> /KE <sub>i</sub>											
60	Trial	KE <sub>i</sub>	δKE <sub>i</sub>	KE <sub>f</sub>	δKE <sub>f</sub>	KE <sub>diff</sub>	δ(KE <sub>diff</sub> )	%				
61		[gm (cm/s) <sup>2</sup> ]	[gm (cm/s) <sup>2</sup> ]	[gm (cm/s) <sup>2</sup> ]	[gm (cm/s) <sup>2</sup> ]	[gm (cm/s) <sup>2</sup> ]	[gm (cm/s) <sup>2</sup> ]	change				
62	1		#DIV/0!		#DIV/0!		#DIV/0!	#DIV/0!				
63	2		#DIV/0!		#DIV/0!		#DIV/0!	#DIV/0!				
64	3		#DIV/0!		#DIV/0!		#DIV/0!	#DIV/0!				
65	4		#DIV/0!		#DIV/0!		#DIV/0!	#DIV/0!				
66	5		#DIV/0!		#DIV/0!		#DIV/0!	#DIV/0!				
67	6		#DIV/0!		#DIV/0!		#DIV/0!	#DIV/0!				
68												
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