

Concepts of this Module

- Impulse-momentum Theorem
- Conservation of Momentum
- Introduction to Conservation of Energy
- Angular Momentum

The Activities



**Course
Concepts**

Activity 1

Setup:

- Make sure the Track is level.
- The Motion Sensor should be mounted on the end of the Track closest to the wall and connected to the DAQ board.
- A Clamp should be attached about half-way down the track for the cart to collide with.
- The Force Sensor with the spring bumper attached should be mounted on the Cart. The spring bumper should not be loose, but it also must not be over-tightened, or the mounting could be damaged. Speak to a TA if you think the bumper is not attached properly. Measure the total mass of the Cart and Force Sensor.
- Place the Cart on the Track with the bumper facing the vertical rod. Connect the Force Sensor to the DAQ board. Press the *Tare* button on the Force Sensor to zero its readings.
- Run the Cart up and down the Track a few times to warm up the bearings in the wheels.
- Set the sample rate for the Motion Sensor to 50 samples per second. Set the sample rate for the Force Sensor to 100 samples per second.

Now the Activities:

- A. You want the spring bumper on the Force Sensor to collide with the vertical rod mounted on the Table Clamp. The Cart will drag the wire connecting the Force Sensor to the DAQ board; make sure it is as free to move as possible. You may need to adjust the position of the Track and/or vertical rod to get a nice “clean” collision.

- B. Take data on the speed versus time using the Motion Sensor and force versus time using the Force Sensor from a second or so before the collision to a second or so after the collision.
- C. From the speed versus time data, what is the momentum of the Cart plus Force Sensor just before the collision? What is the momentum just after the collision? Use the convention that the speed of the Cart before the collision is a positive number, and the speed after the collision is a negative number.
- D. What is the change in the momentum from just before the collision to just after?
- E. From the force-time data, calculate the total impulse exerted on the Cart during the collision: this is the area under the force-time graph. Compare your result to Part D.
- F. Use the software to calculate the total impulse exerted on the Cart. Which result do you think is better, the software's calculation or your estimate in Part E? Explain.
- G. In preparation for Activity 2 of this module, export your speed-time data into a file on the server. Since this is Module 4, Activity 1 Part G, the name of the file could be something like: M4A1PG_vt.



Expt Activity 2

The Physics presented in textbooks almost always deals with ideal cases. For example, in that context we often say “ignore air resistance” or “assume that friction is negligible.” In the real world, often these idealizations are not correct.

For example, we know that there is always friction between the Cart and the Track. In Activity 4, there was additional “friction” because the Cart was dragging the wire of the Force Sensor, and the effect of these two forces is easily seen in the data. . These extra forces are in the opposite direction to the motion of the Cart, so always slow down the *magnitude* of the velocity, regardless of whether the velocity is a positive or negative number.

Here we will investigate some ways of dealing with these terms

- A. Copy the file you saved in Activity 1 to some name like M4A5_vt_Edited.
- B. Use a text editor or spreadsheet program to:
 - Remove all the speed-time data for when the collision is occurring.
 - Change the values of the speeds after the collision to positive numbers. If you are using *Excel* but are not very familiar with this program, Appendix A discusses some ways to do this.
- C. Fit the edited data to a straight line using the *PolynomialFit* program. What is the meaning the slope of the line? If the slope is found to be zero within errors what does this say about the total friction acting on the system?

- D. What is the change in the momentum of the Cart plus Force Sensor during the collision due to these extra forces?
- E. Considering your data and your experience with these Carts, which force do you think is largest, friction or dragging the wire?
- F. What is the change in momentum of the Cart plus Force Sensor during the collision due to the collision itself? How does this value compare with what you found in Part D of Activity 1?
- G. We can eliminate the term due to dragging the wire by mounting the Force Sensor on the vertical rod mounted on the Table Clamp. Now the Force Sensor will measure the force exerted on it by the Cart. How is this related to the force exerted by the Force Sensor on the Cart?
- H. Is this a better procedure than the one you used in Activity 4? Explain.

Course Concepts Activity 3

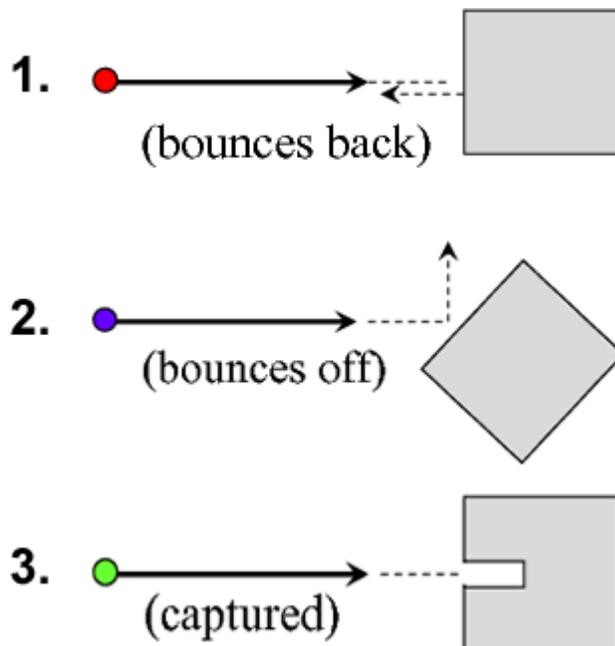
You are asleep in your room, but a fire has broken out in the hall and smoke is pouring in through the partially open door. You need to close the door as soon as possible. The room is so messy you cannot get to the door. You have a ball of clay and a super ball, each with the same mass. If you throw the clay at the door it will stick to it; if you throw the super ball at the door it will bounce off. You only have time to throw one thing at the door.

- A. Which should you throw at the door, the clay or the super ball? Explain.
- B. Which ball will experience the largest impulse during the collision?
- C. From Newton's 3rd Law the impulse that the door exerts on the ball during the collision is equal in magnitude although opposite in direction to the impulse the ball exerts on the door. Which ball exerts the largest impulse on the door?

Course Concepts Activity 4

Three identical balls slide on a table and hit a block that is fixed to the table. In the figures we are looking down from above. In each case the ball is going at the same speed before it hits the block.

Rank in order from the largest to the smallest the magnitude of the force exerted on the block by the ball.




Course Concepts **Activity 5**

An *air track* is similar to the Track you have been using in the Practicals. The track has small holes drilled in it, and air blows out of the holes. Thus the carts for the air track float on the air and there is extremely low friction between the cart and the track. An animation of an air track is at:

<http://faraday.physics.utoronto.ca/PVB/Harrison/Flash/ClassMechanics/AirTrack/AirTrack.html>

There are six possible collisions that may be simulated: three different values for the mass of one of the carts, with elastic “bouncy” and inelastic “sticky” collisions for each value of the mass.

- A. The *momentum* $\vec{p} = m\vec{v}$ is also called the *quantity of motion* and sometimes just the *inertia*. For Newton momentum was central to his thinking about dynamics. Use the animation to determine if the total momentum of the carts is conserved before and after each of the six possible collisions.
- B. For Leibniz, a contemporary and rival of Newton, momentum was not central to his thinking. Instead he concentrated on the quantity mv^2 , which he called the *vis viva* (literally “living force”). Use the animation to determine if the total *vis viva* of the carts is conserved before and after each of the six possible collisions.
- C. Which concept, momentum or *vis viva*, appears to be the most fundamental?

Appendix A – Using Excel

Here is what the raw data file might look like:

	A	B	C
1	Velocity, Ch 1&2, Run #1		
2	Time (s)	Velocity (m/s)	
3	0.0315	0.585	
4	0.0514	0.583	
5	0.0712	0.582	
6	0.0911	0.581	
7	0.111	0.56	
8	0.1308	0.422	
9	0.1506	0.123	
10	0.1704	-0.254	
11	0.1902	-0.485	
12	0.2099	-0.558	
13	0.2297	-0.556	
14	0.2494	-0.555	
15	0.2691	-0.554	
16	0.2889	-0.555	
17	0.3086	-0.553	
18	0.3284	-0.546	
19	0.3481	-0.542	
20			
21			

We will delete rows 7 through 11. Click on the 7 row label. Hold down the Shift key and click on the 11 row label. This will select the rows.

Right click on the highlighted area and choose Delete.

	A	B	C
1	Velocity, Ch 1&2, Run #1		
2	Time (s)	Velocity (m/s)	
3	0.0315	0.585	
4	0.0514	0.583	
5	0.0712	0.582	
6	0.0911	0.581	
7	0.111	0.56	
8	0.1308	0.422	
9	0.1506	0.123	
10	0.1704	-0.254	
11	0.1902	-0.485	
12	0.2099	-0.558	
13	0.2297	-0.556	
14	0.2494	-0.555	
15	0.2691	-0.554	
16	0.2889	-0.555	
17	0.3086	-0.553	
18	0.3284	-0.546	
19	0.3481	-0.542	
20			

Now change all the negative values for the speeds after the collision to positive values. The “brute force” way to do this is to double click on each cell with a negative velocity and manually remove the minus sign, although Excel experts will know of a more elegant way to do this. The result is shown to the right.

Save the file. You may ignore Excel’s mumbling about losing information.

	A	B	C
1	Velocity, Ch 1&2, Run #1		
2	Time (s)	Velocity (m/s)	
3	0.0315	0.585	
4	0.0514	0.583	
5	0.0712	0.582	
6	0.0911	0.581	
7	0.2099	0.558	
8	0.2297	0.556	
9	0.2494	0.555	
10	0.2691	0.554	
11	0.2889	0.555	
12	0.3086	0.553	
13	0.3284	0.546	
14	0.3481	0.542	
15			
16			
17			

This Guide was written in July 2007 by David M. Harrison, Dept. of Physics, Univ. of Toronto. Some parts are based on Priscilla W. Laws et al., **Workshop Physics Activity Guide** (John Wiley, 2004), Unit 8.

Last revision: Nov. 8, 2013 by Andrew Meyertholen.