

Concepts of this Module

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

The Activities

The icon for 'Course Concepts Activity 1', featuring a red target symbol with a bullseye and the text 'Course Concepts' in red and 'Activity 1' in black.

Course Concepts Activity 1

Note: in this Activity you will be using a Force Sensor with a spring bumper mounted on it. Please do not adjust the bumper. If you think it needs adjustment contact your Instructor.

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 Data Acquisition Device.
- A C-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 an Instructor 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 C-clamp. Connect the Force Sensor to the Data Acquisition Device. 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. The sample rate for the Force Sensor is not adjustable and is 100 samples per second.

You will want to “trim” your data after you have collected it using the tools provided by the software. Appendix A is a brief discussion of things you may wish to do. For full details consult the manuals for the Force Sensor and the Motion Sensor, which are available at: <http://www.upscale.utoronto.ca/Practicals/Manuals/Manuals.html>.

Now the Activities:

- A. You want the spring bumper on the Force Sensor to collide with the C-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 C-clamp to get a nice “clean” collision. Here is a photograph of the cart and the C-clamp



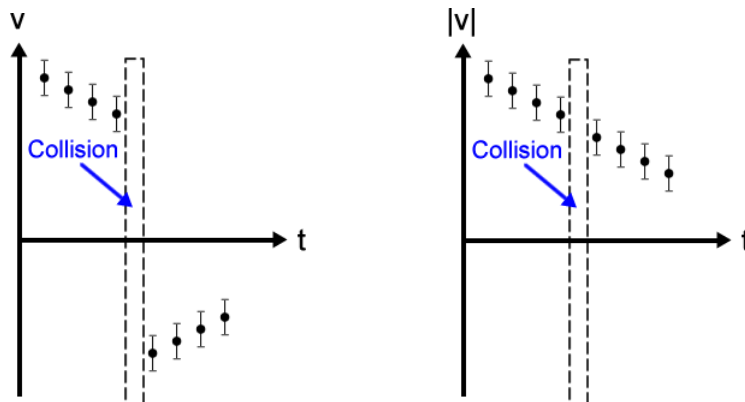
- B. Take data on the speed versus time using the Motion Sensor and force versus time using the Force Sensor from a second or so before the collision to a second or so after the collision. Remember to press the Tare button on the Force Sensor just before taking your data.
- C. From the speed versus time 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, visually estimate 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 1, 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. It is also true that the collision of the spring bumper with the C-clamp is not perfectly elastic.

Here we will investigate some ways of dealing with these terms. The idea is that the *magnitude* of the speed is always decreasing as shown in the two plots below of made-up data. The plot on the left is speed versus time before and after the collision, and the plot on the right is the magnitude of the speed versus time before and after the collision.



By fitting the data in the second plot to a polynomial, the effect of the frictional forces can be quantitatively evaluated.

- 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 B 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? Does adding more powers to the polynomial result in a better fit?
- D. What is the change in the momentum of the Cart plus Force Sensor during the collision due to these extra forces? Can you express your answer including an error term?
- 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? Is this a better value than you got in Part D of Activity 1?
- G. We can eliminate the term due to dragging the wire by mounting the Force Sensor on the mount for the C-clamp. This will require unscrewing the Force Sensor from the Cart and using the provided long screw to mount it to the End Stop. Here is a photograph of the setup, with the screw not tightened so you can see it.



You will, of course, need to tighten the screw so the Force Sensor is firmly mounted. 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 1? Explain.

When you are finished with this Activity, please re-mount the Force Sensor on the Cart using the short screw. Please be sure to use the hole in the Force Sensor labeled **CART**: the other hole has internal threads which you will destroy if you use it instead.

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

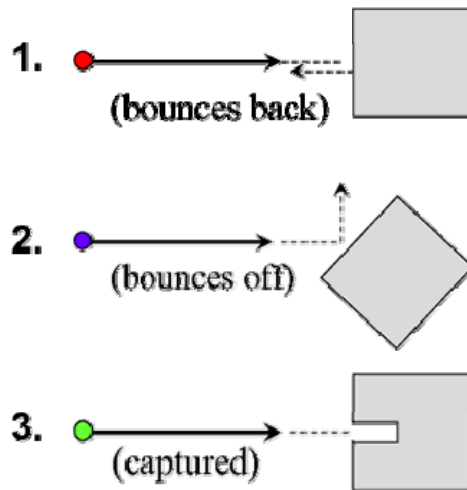
is so messy you cannot get to the door. You have a ball of clay and a super ball, each with the same mass. If you throw the clay at the door it will stick to it; if you throw the super ball at the door it will bounce off. You only have time to throw one thing at the door.

- Which should you throw at the door, the clay or the super ball? Explain.
- Which ball will experience the largest impulse during the collision?
- 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.

- 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.
- 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*

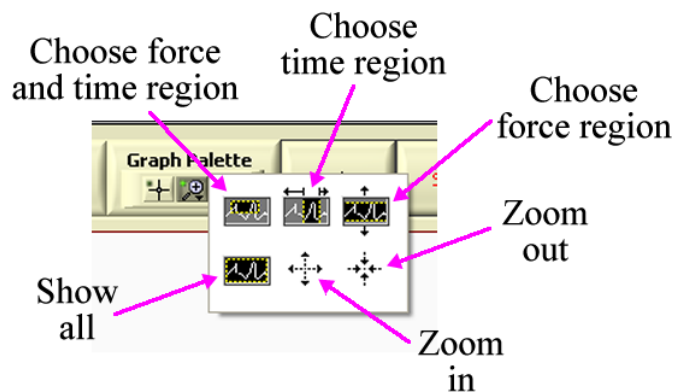
viva (literally “living force”). Use the animation to determine if the total *vis viva* of the carts is conserved before and after each of the six possible collisions.

C. Which concept, momentum or *vis viva*, appears to be the most fundamental?

Appendix A – “Trimming” the Data

For the data collected by the Motion Sensor, you will want to select the velocity versus time data for times just before the collision to just after the collision. In the **Analyze** tab use the mouse to grab the cursors in the left-hand plot of Distance versus Sample to select the desired region. The graphs to the right of this plot show only the data between the two cursors.

For the Force Sensor data, you will similarly want to look at the force versus time data for times just before to just after the collision. In the upper-right corner of the Force Sensor vi is a item labeled **Graph Palette**. Clicking on the middle of the three buttons in the palette shows a pull-down menu as shown. Select **Choose time region** and “paint” in a region of time values on the graph to display only force-time data for the selected region. The **Show all** item undoes any previous selections and displays all the data.



In calculating the impulse $J = \int F dt$ from the force-time data you can use the **Integrate** button on the front panel of the Force Sensor vi. This function calculates the area under the curve between the two cursors, which are called **Cursor 0** and **Cursor 1**. To move the cursors with the mouse, choose the left-hand button in the Graph Palette, whose icon is the crossed lines that can be seen in the above figure.

Appendix B – 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.

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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.

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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.

Revisions by David M. Harrison, Jason Harlow, and Lilian Leung. Last revision: March 9, 2011.