

The Collision Impulse.

Equipment Needed	Qty	Equipment Needed	Qty
Economy Force Sensor (CI-6746)	1	Balance (SE-8707)	1
Photogate/Pulley System (ME-6838)	1	Collision Cart (ME-9454)	1
Accessory Bracket (CI-6545)	1	1.2 m Track System (ME-9435A)	1

What Do You Think?

How is the force felt during a collision related to the duration of the collision?

Take time to answer the ‘What Do You Think?’ question(s) in the Lab Data Sheet section.

Background

When an object strikes a barrier, the force on the object varies as the collision occurs. Changes in the linear momentum of the object (the *impulse*) can be calculated in two ways:

- Using the velocities before (v_i) and after (v_f) the collision: $\Delta p = mv_f - mv_i$
- Using the net force and time of impact: $\Delta p = F\Delta t$

It is possible for the object to undergo the same change in momentum whether it is involved in an abrupt hard collision or a cushioned collision. We want to determine the difference between how a hard or soft collision affects the force felt by the object.

For You To Do

Use the Photogate System to measure the motion of a cart as it collides with a bumper. Use a force sensor mounted on the track to measure the force of the collision over the same interval of time. Use *Capstone* to compare the change in the linear momentum of the cart with the integral of the measured force vs. time graph.

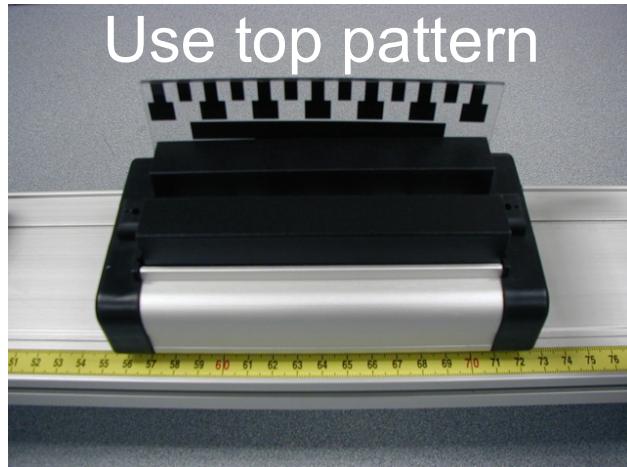
You will need to take the effects of friction into consideration when you interpret your data. By making several measurements of the velocity you should be able to correct for the effect of friction. How? That is up to you to figure out.

PART I: Computer Setup

1. Make sure that the ScienceWorkshop interface is connected to the computer and turned on (look for the green light on the front panel of the interface).
2. Connect the photogate's stereo phone plug to Digital Channel 1 of the interface.
3. Find the force sensor in your red box, and connect its connector to Analog Channel A of the interface (note: the connectors of the analog channel need to be properly aligned).
4. Download the setup file *Impulse.cap.zip* for this measurement from the Physics 141 web site (select Laboratories -> Lab 3 from the toolbar). The setup file will be downloaded as a zip file. It should be expanded automatically.
5. Open the *Capstone* program by clicking on the icon in the Dock.
6. After the program opens, select the “Open Experiment” option from either the top toolbar or the “File” menu and navigate to your desktop to open the document entitled *Impulse.cap* that was downloaded from the Physics 141 web site.
7. The *Capstone* document opens with a Graph display that shows graphs of the Force versus Time and the Velocity vs Time.
8. Before proceeding, select “Save As” from the file menu to ensure that you can save the data you will collect. Use a new filename that clearly identifies this file as belonging to you (e.g. I may use as filename *ImpulseFW101507.cap*.)
9. **Make sure that you save your work frequently so that you do not lose any large amount of data if computing problems occur.**

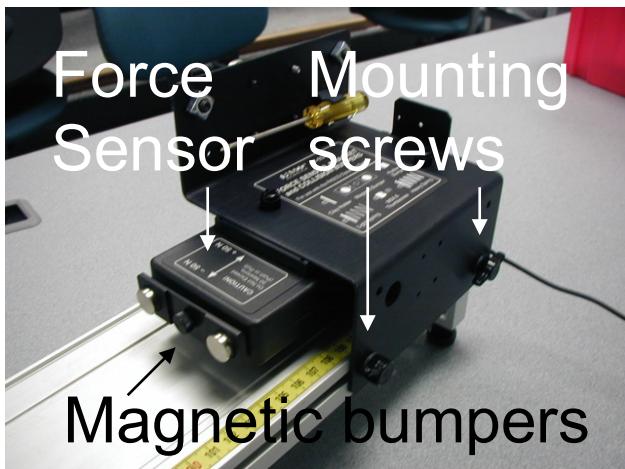
**PART II: Sensor Calibration and Equipment Setup**

1. You do not need to calibrate the photogate, but make sure that the proper band spacing is used in the setup. We will be using the top pattern of the picket fence for this experiment (see picture). Measure the spacing between the opaque bands on the picket fence. To change the default setting to another value, select “Hardware Setup” from the left toolbar, click on the picture of the photogate and then click on the photogate “Properties” symbol. A



window will open that will allow you to change the “Flag Spacing.” Note that the spacing is measured in meters. Enter the correct value for the spacing of the opaque bands on your picket fence and click OK.

2. Connect two support legs to both ends of the track (see the picture).
3. Place the Dynamics Track on a horizontal surface. Level the Dynamics Track by placing a cart on the Dynamics Track. If the cart rolls one way or the other, use the adjustable feet at one end of the Dynamics Track to raise or lower that end until the Dynamics Track is level and the cart does not roll one way or the other.
4. Install the photogate near the end of the track where we will mount the force sensor. Make sure that the photogate is set to the appropriate height so that its light beam intercepts the top band of the picket fence.
5. Use the thumbscrews included with the Force Sensor to mount the sensor onto the force sensor bracket. If the magnetic bumpers are installed on the sensor, take the bumpers off and install the hook attachment.
6. Mount the bracket in the T-slot on the side of the Dynamics Track (see picture).
7. Press the Tare button on the side of the sensor.
8. We first need to calibrate the force sensor. We will do this using the pulley and a few masses hanging from the hanger. Connect a pulley to the track, as shown in the setup of your instructor, get some string, connect a hanger on one end and make a loop at the other end to connect it to the hook attachment of the force sensor.
9. Click on the “Calibration” button in the left toolbar. Select “Force” as the type of measurement you would like to calibrate. Select “Two Standards (2 points)” as the type of calibration you would like to perform.



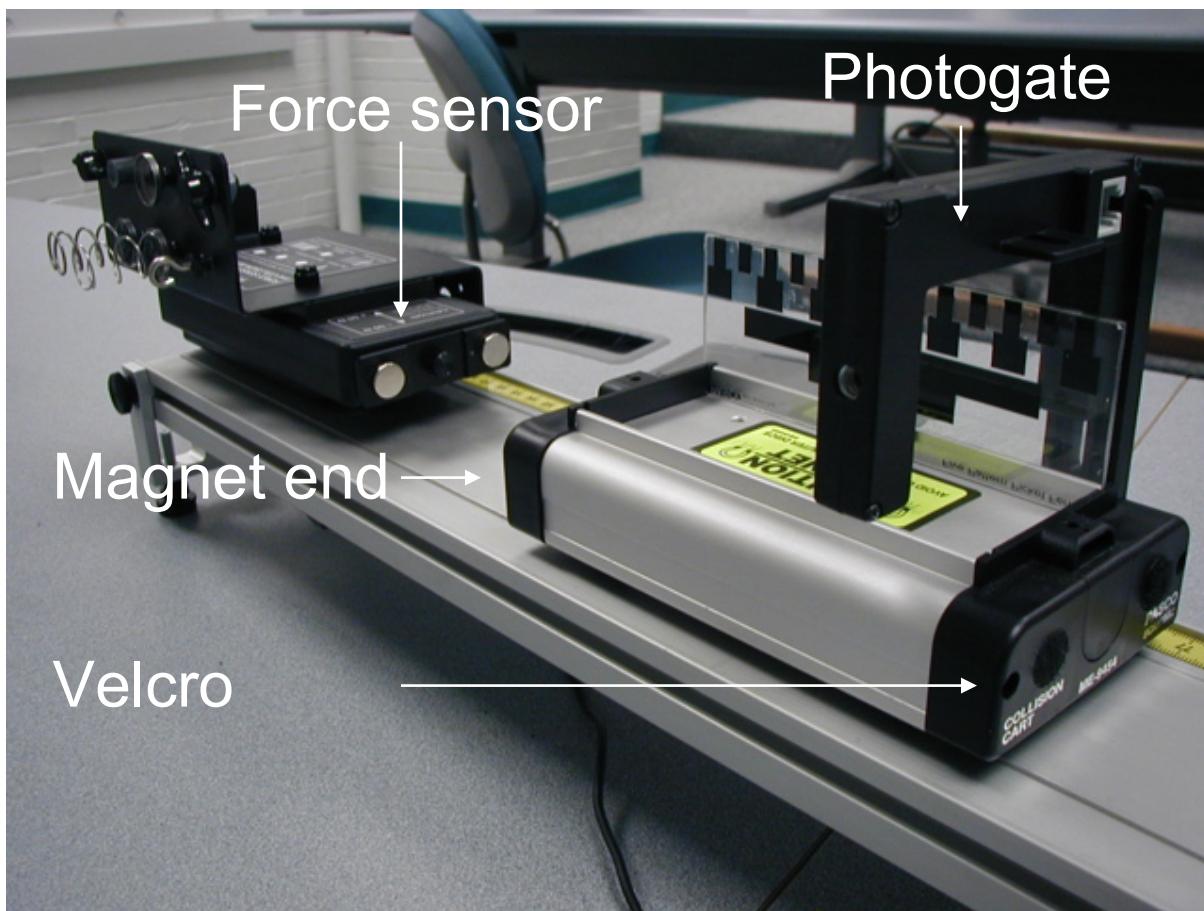
10. Hang a mass on the hanger. Using the known mass, you can calculate what the force is that is exerted on the force sensor. Enter this force in the “Standard Value” box and click the “Set Current Value to Standard Value” button. Repeat this procedure with a different weight and then press finish. The sensor should now be calibrated.
11. Remove the pulley and the string and return the items used to calibrate the force sensor to the boxes.
12. Unscrew the hook attachment from the front of the force sensor and replace it with the magnetic bumpers.
13. The setup should now look similar to the one shown in the picture on the following page. Note: you need to make sure that the photogate is positioned close to the force sensor, but sufficiently far away that the cart will not feel the magnetic collision force while moving through the photogate.

Calibration

- 1 Choose the type of measurement you would like to calibrate:
 Force
- 2 Choose the probes you would like to calibrate now:
 ▾ Force Measurements
 Force Sensor, Ch A : Force, ChA
- 3 Choose the type of calibration you would like to perform:
 Two Standards (2 point)
 One Standard (1 point offset)
 One Standard (1 point slope)
 Restore Factory Calibration
 Review Current Calibration
- 4 Calibrate the first point:
 Standard Value N
 Current Value N
- 5 Calibrate the second point:
 Standard Value N
 Current Value N

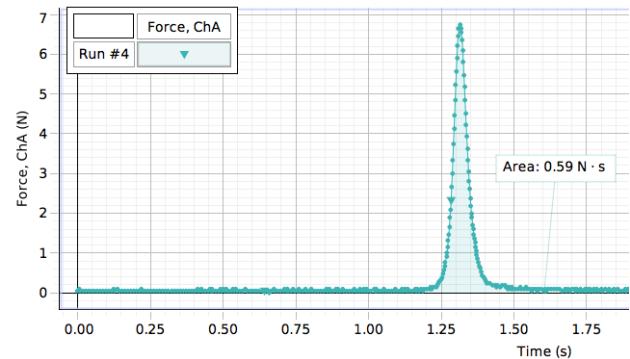
PART III: Data Recording

1. Place the cart on the Dynamics Track.
2. Begin data recording.
3. Give the cart a gentle push; make sure that it does not touch the bumper on the force sensor.
4. End data recording after the cart has rebounded from the collision with the force sensor's magnetic bumper and has passed through the photogate a second time.
5. After each measurement, before proceeding to the next measurement, immediately analyze the data you have collected (see the "Analyzing the Data" section).
6. Take a few different measurements with varying initial velocities and varying cart masses.



PART IV: Analyzing the Data

1. Examine the Force versus Time plot. Make sure that the region on the left and the right of the peak has an average force of 0 N. If this is not the case, you will need to recalibrate your sensor.
2. Click on the area button () to find the area under the curve. Record the value of the area under the curve in the Data Table in the Lab Report section.
3. Find the velocity just before the collision and the velocity just after the collision from the velocity versus time plot. You will need to develop a procedure to extract this information from the data. As a result of friction you will observe a time dependence of the velocity. However, from the observed time dependence of the velocity you can determine what the velocity right before and right after the collision is (note that the velocity and force diagrams are shown on a common time axis).
4. Determine the work done by the friction force during the time the collision force acts.
5. Record the two velocity values and the work done by the friction force in the data tables in the Lab Data Sheet section.
6. Use the mass and velocity values to compute the momenta before and after the collision



Laboratory Data Sheet - The Collision Impulse

What Do You Think?

How is the force felt during a collision related to the duration of the collision?

Data Tables

Item					
Run #					
Mass (kg)					
Impulse (Ns)					
Initial Velocity (m/s)					
Final Velocity (m/s)					
Initial Momentum (kg m/s)					
Final Momentum (kg m/s)					
Change in momentum (kg m/s)					
Work done by friction (J)					

Item					
Run #					
Mass (kg)					
Impulse (Ns)					
Initial Velocity (m/s)					
Final Velocity (m/s)					
Initial Momentum (kg m/s)					
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Change in momentum (kg m/s)					
Work done by friction (J)					

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Final Velocity (m/s)					
Initial Momentum (kg m/s)					
Final Momentum (kg m/s)					
Change in momentum (kg m/s)					
Work done by friction (J)					

Questions

1. For your data, how does the change in momentum compare to the impulse?
 2. What are possible reasons why the change in momentum is different from the measured impulse?

3. Compare the impulse and force for an abrupt (hard) and a cushioned (soft) collision. Use words and also sketch the force vs. time graphs.
 4. Use the above comparison to explain why airbags in cars can help to prevent injuries to the occupants during a frontal collision.