The Impulse-Momentum Theorem

Name:

Lab Section Number:

Pre-Lab Exercises:

1. What formula is typically used to represent the impulse-momentum theorem?

2. How many force peaks should you integrate throughout the course of this laboratory experiment?

3. How many total graphs do you need to print?

4. For a given change in momentum, what effect will a longer time period have on the net impulse?
Introduction: The Impulse-Momentum theorem finds use in many different daily situations, but it is particularly noticeable as the reason for airbags in automobiles. The airbag causes the same change in momentum, and hence the same impulse, but spreads the impulse out over a longer time interval, thus reducing the magnitude of the force on the passenger. The purpose of this experiment is to confirm the impulse momentum theorem within the limits of experimental error.

Materials

Science Workshop interface  Bubble Level
Dynamics Track  Masses
Dynamics Cart  Balance (500 grams +)
Motion Sensor  Force sensor bracket.
Force Sensor  Wooden blocks

1. Setting up the equipment.
1.1 Connect the Science Workshop interface to the computer, turn on the interface and then turn on the computer. (this may have already been done for you)
1.2 Open the Data Studio software package by double clicking on the icon from the desktop menu. Select Create Experiment
1.3 You will see an Experiment set up screen listing the types of sensors available to us. Scroll down the list of sensors and double-click the Motion Sensor device. This will add it to the interface box diagram, showing the proper connections: yellow into Digital Channel 1, black into Digital Channel 2. Connect the leads as indicated.
1.4 Find the force sensor device and double click on this. This will add it to the interface box diagram showing you the proper connections.
1.5 The sensor icons will appear in the Experiment Setup window. Double-click on the motion sensor to bring up the settings options: Here you can select several options including measuring displacement, velocity and acceleration.
1.5.1 Under the Measurement tab, see that the Velocity checkbox is selected.
1.5.2 Under the Motion Sensor tab, set the Trigger Rate to 100 and click OK. This is the frequency that the sensor will take displacement readings. Through the course of this experiment, manipulate this setting to achieve the best graph.
1.6 Double click on the Force Sensor icon and set the sample rate to 200 Hz. Tare your force sensor now. Make sure that there are no external forces acting on the sensor.
1.7 Close the experiment setup window
1.8 Under the display window on the lower left, select the type of display you would like. For this experiment we will select “graph”.
1.9 Select force as the desired graph output.

2. Measuring the Impulse and Momentum
2.1 Connect the force sensor to the force sensor bracket and connect this to the dynamics track so that when the bracket is placed against the bumper, the force “button” will be facing the middle of the track. Attach the bumper magnets to the force sensor. (This has probably been done for you.)
2.2 Connect the motion sensor to the end of the track without the leveling screw.
2.3 Adjust the leveling screws until you have leveled the track.
2.4 Raise one end of the cart using the wooden blocks so that you create a small angle less than 10 degrees and calculate this angle. Then calculate the estimated acceleration of the cart down the plane.
2.5 Tare the force sensor by pushing the tare button (through the hole in the side of the force sensor bracket). Make sure nothing is touching the force sensor while you are doing this.
2.6 Place the cart (with the plunger side facing away from the force sensor) about halfway up the track and record this position.
2.7 Press the start recording button on the DataStudio and then release the cart letting the cart roll towards the force sensor. Stop recording once the cart has bounced several times. Be sure to hold the track in place while the cart is striking the bumper.

Note: If the cart scatters off the track lower the angle of the track, or start from a lesser distance up the incline.

2.8 You will notice the force time graph looks like a series of bumps on an otherwise straight graph.
2.9 Select one of these “bumps” by highlighting it and integrate the force over the duration of the bounce. You do this by finding the area under the curve.

2.9.1 Highlight the desired “Bump” and select the sigma button and select area. This will display the impulse on the cart during the collision with the bumper. Note the value with units of this impulse (area).

2.9.2 What is the duration of this collision? You will find it useful for one of the questions at the end of the lab.

2.10 Next calculate the change in momentum by plotting a momentum graph.

2.10.1 You will have to use the Calculate function to define the momentum function.

2.10.2 Input a formula to calculate the momentum (the usual equation will do) and click “Apply.” Define your mass and velocity variables in the “Variables” box below.

2.10.3 In the “Properties” section, define the “Name,” “Variable Name” and “Variable Units” appropriately.

2.10.4 After getting back to the graph, drag the momentum data onto the graph. (You should get a split screen graph). You should lock the axes so that the time base for both the impulse and the momentum are the same.

2.10.5 Select a sudden change in momentum (as shown in the diagram above) that corresponds to a change in impulse you have already measured and use the sigma button to display maximum and minimum values.

2.11 Record both the impulse observed and the change in momentum for three bounces.

2.12 Repeat steps 2.5 through 2.11 with one additional mass on the cart.
2.13 Repeat steps 2.5 through 2.11 with no masses, this time with the cart at half the distance up the track and record this initial position. Now the velocity of the cart just before it collides with the force sensor will be less than before.

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<th>Angle of Incline</th>
<th># of Black masses</th>
<th>Mass of System (kg)</th>
<th>Distance up ramp (m)</th>
<th>Initial Momentum (kg*m/s)</th>
<th>Final Momentum (kg*m/s)</th>
<th>Change in Momentum (kg*m/s)</th>
<th>Measured Impulse (N*s)</th>
<th>Time of Collision (s)</th>
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3. Questions
3.1 What was the average percent difference for your trials? Does this confirm the impulse momentum theorem? Why or why not?
3.2 What would explain possible differences between measured impulse and change in momentum? In particular, why is the change in momentum negative, while the impulse is positive?
3.3 The impulse momentum theorem assumes there is no net outside force acting on the object but clearly there is in this case or the cart would not be accelerating. Neglecting frictional forces, what is this force?
3.4 Attempt to correct the existing impulse-momentum data by including the impulse due to this outside force. Note that your corrections might not produce exact agreement either.
3.5 Describe any differences between the results of 2.12 and the results of the original run with no mass on the cart.
3.6 Does the impulse momentum theorem still hold for this case?
3.7 Print one set of impulse and change in momentum graphs and put these on the same sheet to save paper.
3.8 Include your results in a tabular format. A spreadsheet is best suited both for performing these calculations, and for presenting them neatly. The table should everything in the above table, as well as the percent difference between impulse and change in momentum, the “corrected” impulse (via question 3.4) and the percent difference for your “corrected” results.