

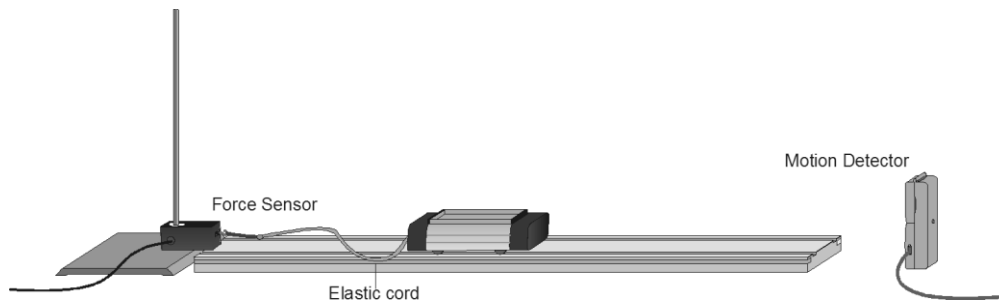
Impulse and Momentum Lab

The impulse-momentum theorem relates impulse, the average force applied to an object times the length of time the force is applied, and the change in momentum of the object:

$$\overline{F}\Delta t = mv_f - mv_i$$

Here we will only consider motion and forces along a single line. The average force, \overline{F} , is the *net* force on the object, but in the case where one force dominates all others it is sufficient to use only the large force in calculations and analysis.

For this experiment, you and your team will determine which type of material would be ideal to keep a runaway child on a harness from suffering injury.



OBJECTIVES

- Measure a cart's momentum change and compare to the impulse it receives.
- Compare average and peak forces in impulses.

MATERIALS





computer
Vernier[®] computer interface
Logger Pro[®]
Vernier[®] Motion Detector
Vernier[®] Force Sensor

dynamics cart and track
clamp
elastic band
rope
500 g mass

PRELIMINARY QUESTIONS

1. In a car collision, the driver's body must change speed from a high value to zero. This is true whether or not an airbag is used, so why use an airbag? How does it reduce injuries?
2. You want to close an open door by throwing either a 400 g lump of clay or a 400 g rubber ball toward it. You can throw either object with the same speed, but they are different in that the rubber ball bounces off the door while the clay just sticks to the door. Which projectile will apply the larger impulse to the door and be more likely to close it?

PROCEDURE

1. Measure the mass of your dynamics cart and record the value in the data table.
2. Hold your sensor vertically and click  Zero, to calibrate.
3. Place the track on a level surface. Confirm that the track is level by placing the low-friction cart on the track and releasing it from rest. It should not roll. If necessary, adjust the track.
4. Attach the elastic band to the cart and then the band to the force sensor.
5. Practice releasing the cart so it rolls toward the Motion Detector, bounces gently, and returns to your hand. The Force Sensor must not shift and the cart must stay on the track. Arrange the cord and string so that when they are slack they do not interfere with the cart motion. You may need to guide the elastic band/string by hand, but be sure that you do not apply any force to the cart or Force Sensor. Keep your hands away from between the cart and the Motion Detector.
10. Click  Collect to take data; roll the cart and confirm that the Motion Detector detects the cart throughout its travel. Inspect the force data. If the peak exceeds 10 N, then the applied force is too large. Roll the cart with a lower initial speed. If the velocity graph has a flat area when it crosses the time-axis, the Motion Detector was too close and the run should be repeated.
11. Click the Statistics button, , and read the average velocity. Record the value for the initial velocity in your data table. In the same manner, choose an interval corresponding to a time when the elastic was again relaxed, and the cart was moving at approximately constant speed toward the Force Sensor. Drag the mouse pointer across this interval. Click the statistics button and read the average velocity. Record the value for the final velocity in your data table in the same manner.
12. Now record the time interval of the impulse. On the force vs. time graph, drag across the impulse, capturing the entire period when the force was non-zero. Find the average value of the force by clicking the Statistics button, , and also read the length of the time interval over which your average force is calculated. Record the values in your data table.
13. Perform a second trial by repeating Steps, record the information in your data table.
14. Change the elastic material attached to the cart to the rope.
15. Repeat Steps, record the information in your data table for rope experiment.

IMPULSE-MOMENTUM LAB

DATA TABLE

Total mass of cart	kg
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Trial	Final Velocity v_f (m/s)	Initial Velocity v_i (m/s)	Average Force F (N)	Duration of Impulse Δt (s)	Impulse (N·s)
Elastic Band					
1					
2					

Rope					
1					
2					

Trial	Impulse $F\Delta t$ (N·s)	Change in momentum (kg·m /s) or (N·s)	% difference between Impulse and Change in momentum (N·s)
Elastic Band			
1			
2			

Rope			
1			
2			

Use this space to show work for calculations.

ANALYSIS

1. If the impulse-momentum theorem is correct, the change in momentum will equal the impulse for each trial. Experimental measurement errors, along with friction and shifting of the track or Force Sensor, will keep the two from being exactly the same. One way to compare the two is to find their percentage difference. Divide the difference between the two values by the average of the two, then multiply by 100%. How close are your values, percentage-wise? Does your data support the impulse-momentum theorem?
2. Look at the shape of the last force vs. time graph. Is the peak value of the force significantly different from the average force? Is there a way you could deliver the same impulse with a much smaller force?
3. When you used the rope, what changes occurred in the shapes of the graphs? Is there a correlation between the type of material and the shape of the graph?
4. When you used a stiffer or tighter elastic material, what effect did this have on the duration of the impulse? What affect did this have on the maximum size of the force? Can you develop a general rule from these observations?
5. With the data you now have, would you recommend using a harness with an elastic band or rope attached to a child harness.

