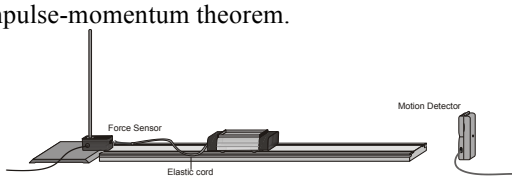
Momentum and Impulse

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, a dynamics cart will roll along a level track. Its momentum will change as it reaches the end of an initially slack elastic tether cord, much like a horizontal bungee jump. The tether will stretch and apply an increasing force until the cart stops. The cart then changes direction and the tether will soon go slack. The force applied by the cord is measured by a Force Sensor. The cart velocity throughout the motion is measured with a Motion Detector. Using Logger *Pro* to find the average force during a time interval, you can test the impulse-momentum theorem.



OBJECTIVES

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

MATERIALS

Computer	Air Track and Glider
Interfaces	Glider Sail
Force Sensor	Elastic cord
Motion Sensor	Mass Sets
Utility Clamp	Ring Stand Rod.

PRELAB 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. Setup the air track with a motion sensor on the end without the hose and a force sensor on the end with the air hose.
2. Attach a glider to the force sensor with an elastic cord approximately 1meter long.
3. Open up the file Lab 06-1 Momentum Impulse Theorem.cap in the Capstone Folder in the pub drive.
4. Connect a motion sensor to the computer through the interface
5. Connect a force sensor to the computer through the interface.
6. Make sure that there are 2 graphs in the program. 1 for force and the other in 1 for displacement.
7. In capstone click record
8. Tare the force sensor with the button on the device.
9. Stop recording.
10. Turn the air on to full.
11. Click record again.
12. Using the side peg of the glider, push the glider down the track towards the motion sensor.
13. Once the glider has bounced back stop recording.
14. Using the slope tool determine the velocity before and after the string pulls on the glider.
15. Measure the mass of the glider with the balance.
16. Calculate the momentum and the change in momentum.
17. Using the coordinate tool measure the change in time between the start of the impulse force and the end of the force.
18. Using the coordinate tool measure the distance between the initial fore and the maximum force.
19. Using 1/2*b*h calculate the air of the force triangle. (Note the average force is ½h and b is change in time)
20. How does this compare to the change in momentum?
21. Double check your answer using the area tool to measure the area between the x-axis and the curve created by the force vs time graph.
22. Complete all calculations and questions.
23. Repeat steps 11 through 22 with an additional 100 grams onto the glider.

DATA TABLE

Mass of cart	kg

Trial Elastic 1	Final Velocity v_f (m/s)	Initial Velocity v_i (m/s)	Change of Velocity Δv (m/s)	Average Force F (N)	Duration of Impulse Δt (s)
1					
2					

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

POSTLAB QUESTIONS

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? Do 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. Revisit your answers to the Preliminary Questions in light of your work with the impulse-momentum theorem.

4. When you use different elastic materials, what changes occurred in the shapes of the graphs? Is there a correlation between the type of material and the shape?

5. 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?