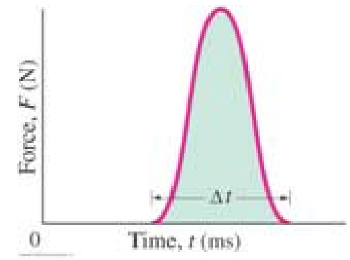
# Impulse and Momentum




Another way to express Newton's Second Law is in terms of impulse and momentum. $\sum \vec{F} = m\vec{a}$ is the same thing as $\int_{t_1}^{t_2} \vec{F}\,dt = m\vec{v_f} - m\vec{v_i}$. The quantity $\int_{t_1}^{t_2} \vec{F}\,dt$ is known as Impulse, $\vec{I}$.

If the force acts over a short period of time the integral representing the impulse can be approximated with $\vec{F}_{net}\Delta t$, and the impulse – momentum equation can be written as $\vec{F}_{net}\Delta t = m\vec{v_f} - m\vec{v_i}$.

Since impulse is an integral, its graphical interpretation is the area under the curve when force is plotted versus time. The shaded area in the graph on the right represents the impulse delivered by the force.

In this experiment you will examine the motion of a cart and the force applied to it in a series of elastic and inelastic collisions. For each type of collision, you will compare the magnitude of impulse with the magnitude of the change in momentum of the cart. You will also compare the impulse delivered to the cart during elastic collisions with the impulse during inelastic collisions.

## Warm-up Question

Suppose a large block of ice is at rest on the surface of an icy driveway, and you want to move it by throwing something at it. You have a piece of clay and a bouncy ball both with the same mass. Which one should you throw at the block to make it move with a greater speed – the piece of clay or the bouncy ball (in other words, which one delivers a greater impulse to the block of ice)? Explain your reasoning.

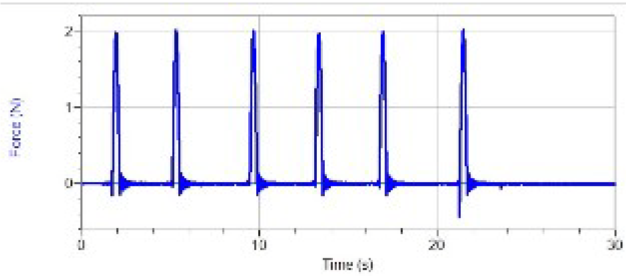
## Materials

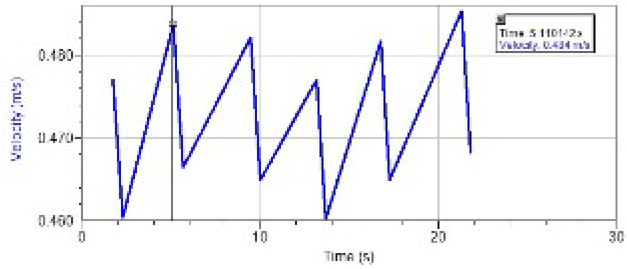
| | | |
|---|---|---|
| Dynamic Cart and track | Photogate bracket | Force Probe |
| Picket fence for cart | Vernier Photogate | Triple Beam Balance |
| Bumper and Launcher with two hoop springs | Clay | |

## Procedure – Elastic Collision (Force probe set to ±10N – Collect 250samples/sec)

1. Set the button on top of the force sensor to ±10N. In Logger Pro, open folder, go to UPJ folder and open the Elastic Collision experiment file.
2. Attach a hoop spring to the force sensor and place the force sensor on the track against the end stop. Attach a photogate to the track at about 20cm away from the force sensor and a picket fence to the cart. On the other end of the track, place the track bracket from the Bumper and Launcher Kit at about 40cm from the photogate, and attach the other hoop spring to the bracket.


3. Zero the force probe.
4. When you start collecting data, the software runs for 30s and that is enough time to collect data for five elastic collisions. Push the cart against the hoop spring attached to the bracket to compress the spring by 4cm. Start data collection, and release the cart. The cart passes through the photogate, makes an elastic collision with the hoop spring attached to the force sensor, bounces back, and passes through the photogate again. After the cart has completely cleared the photogate on its way back, grab it and repeat the process. Make sure the cart is launched from the same compression of the hoop spring every time. Collect data for five elastic collisions. Your data should look like what is shown here (six collisions are shown.)

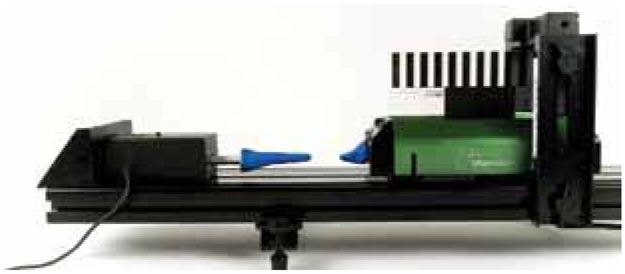



5. Use the *Examine* feature of Logger Pro to read and record the speed of the cart before and after each collision. Then use the *Integral* feature to determine the impulse during each collision. Include the area under all the bumps after the collision.
6. Measure and record the mass of the cart and the picket fence. Calculate the change in momentum of the cart during each collision.
7. Find the percent difference between the average change in momentum of the cart with the average impulse for the five collisions. Comment on your results.
8. Save this file on the desktop.

**Procedure – Inelastic Collision (Force probe set to ±50N – Collect 250samples/sec)**

1. Set the button on top of the force sensor to ±50N. In Logger Pro, open folder, go to UPJ folder and open the Inelastic Collision experiment file.
2. Replace the hoop spring attached to the force sensor with a piece of clay rolled into a cone. Also put a small piece of clay on the front of the cart. Set the switch on top of the force sensor to ±50N.



3. This time you will collect data for one collision at a time. Zero the force probe before each run.
4. Push the cart against the hoop spring and compress the spring by exactly the same length you used for elastic collisions. One person in the group should hold the force sensor firmly in place. Start collecting data, then launch the cart.
9. Record the speed of the cart. Use the *Integral* feature to determine the impulse during the collision. Include the area under all the bumps after the collision.
5. Repeat steps 2 through 4 till you have data for five collisions.
6. Find the percent difference between the average change in momentum of the cart with the average impulse for the five collisions. Comment on your results.
7. Find these ratios and comment on your results. $\frac{\Delta P_{elastic}}{\Delta P_{inelastic}}$ and $\frac{I_{elastic}}{I_{inelastic}}$
8. To compare the profile of the force during an elastic collision with that of an inelastic collision, we must view the two graphs of force vs time on the same scale. While the force vs time graph of the last inelastic collision still displayed on the screen, open the data for the elastic collision (answer No when the window pops up!). Manually adjust the scale to focus on only on force vs time curve. Then adjust the scales further to display both graphs of force vs time for elastic and inelastic collisions on the same force and time scales. Print the graphs and comment on your results.
9. Based on the results of this experiment, do you think you answered the Warm-Up question correctly? Explain.

**Mass of cart and picket fence: -----------------**

**Mass of cart, picket fence, and clay: -----------------**

**Elastic Collision**

| Initial Velocity (m/s) | Final Velocity (m?s) | ΔP (kgm/s) | Impulse (N.s) |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| Average: | | | |

**Inelastic Collision**

| Initial Velocity (m/s) | ΔP (kgm/s) | Impulse (N.s) |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| Average | | |