Momentum and Impulse

Class Notes

Guiding Questions

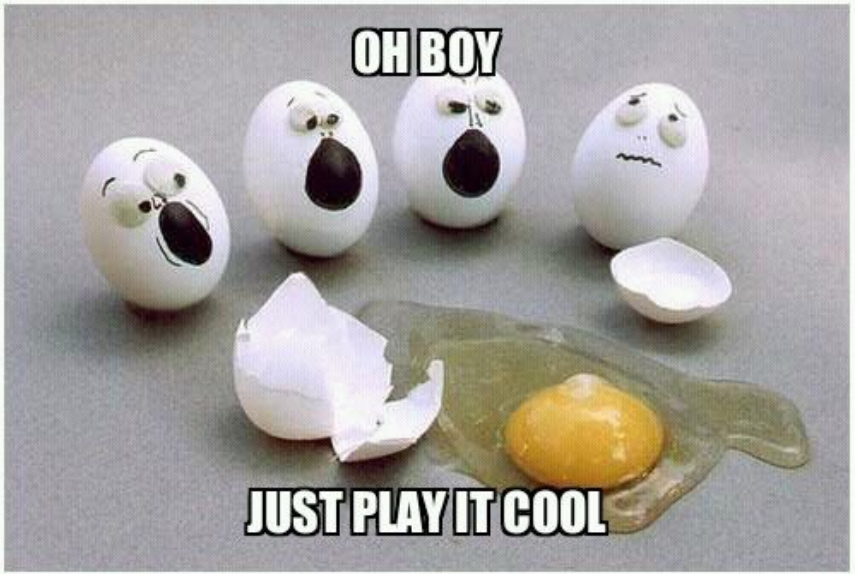
We are continuing to explore topics related to our initial guiding questions:

- How can one explain and predict interactions between objects and within systems of objects?
- How can one predict an object's continued motion, changes in motion, or stability?

Objective

Apply scientific and engineering ideas to design, evaluate, and refine a device that *minimizes* the force on a macroscopic object during a collision.

Yes, this will be similar to the traditional physics egg drop challenge!



New Term: Impulse

What are your initial thoughts on the physics meaning of this new term? Be prepared to share.

Hint: It is related to momentum.

Change in Momentum

We have learned that momentum depends on mass and velocity of an object, both of which are directly related to momentum itself.

Therefore $p = m\Delta v$.

Note the small change with the addition of the delta symbol. What if we change the momentum of an object (Δp)? This leads us to **impulse**.

Consider this Scenario

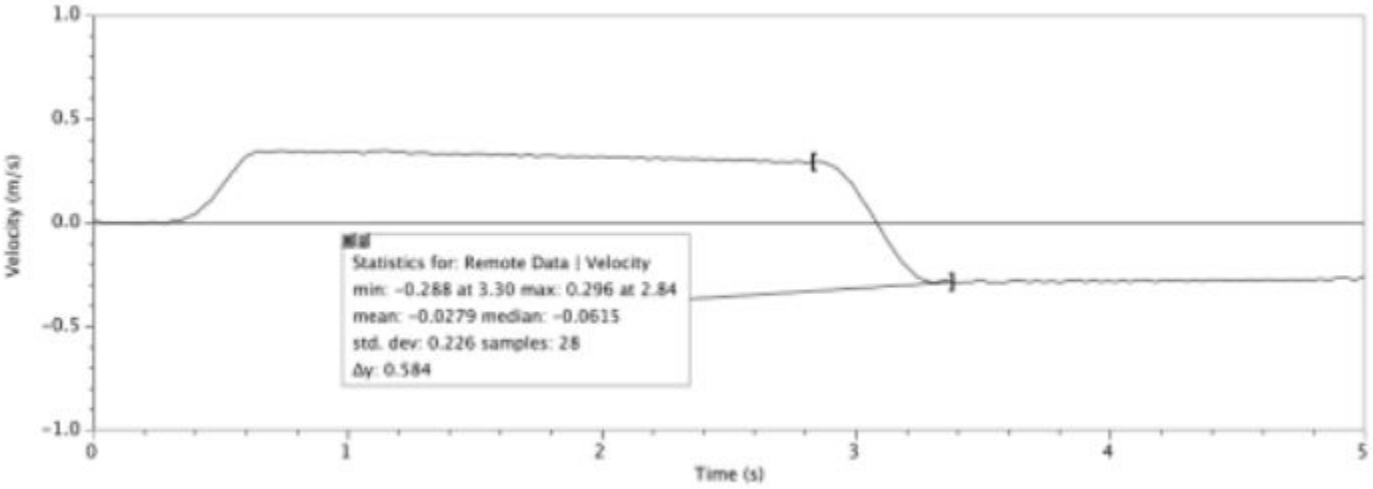
A hoop spring is attached to the front of a cart, which is monitored by a motion detector collecting velocity-time data. Your teacher pushes the cart toward a force sensor with constant velocity so that the hoop spring makes contact and contracts.

***In your notebook, predict the following two graphs:

- Velocity vs. time before, during, and after the collision
- Force vs. time before, during, and after the collision

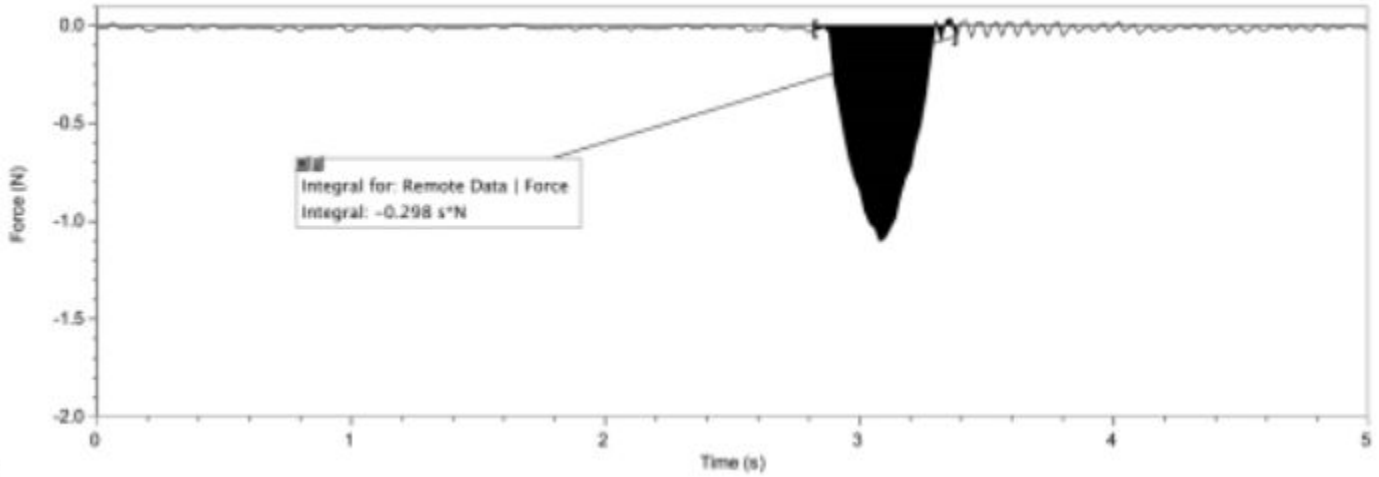
Scenario Analysis - Velocity vs. Time

The velocity of the cart is relatively constant when not in contact with the spring, but changes during the interval over which the spring applies a force to the cart.



Scenario Analysis - Force vs. Time

The negative values for the force-time graph indicate that the force was applied in the direction opposite the initial motion (+). You should note that the velocity after the cart is no longer in contact with the sensor is also negative.



Reflection - Newton's Second Law

$$F = ma$$

We see momentum on one side of the equation and a net external force acting on the system for a period of time on the other side of the equation.

$$F = m\frac{\Delta v}{\Delta t}$$

"**Impulse**" is defined as a net external force acting on a system for a certain length of time, and its symbol is "J."

$$F\Delta t = m\Delta v$$

It is also the area under the curve for a force vs. time graph!

Impulse Equation

$$F = ma$$

The units for impulse are N*s, which is equivalent to kg*m/s.

$$F = m\frac{\Delta v}{\Delta t}$$

Impulse is essentially a force applied over a certain length of time, similar to how work is a force applied over a certain distance. Impulse is the integral of force in situations such as collisions.

$$F\Delta t = m\Delta v$$

The final equation listed is called the **impulse-momentum theorem**.

Project Overview

Objective

Apply scientific and engineering ideas to design, evaluate, and refine a device that *minimizes* the force on a macroscopic object during a collision.

Major Goals

- Incorporate the concept that for a given change in momentum (impulse), force in the direction of the change in momentum is decreased by increasing the time interval of the collision ($F\Delta t = m\Delta v$)

- Explicitly make use of the principle above so that the device has the desired effect of reducing the net force applied to the object by extending the time the force is applied to the object during the collision

Project Phases

You can work individually or with a partner of your choice (recommended). No groups of three.

- Essentially, you'll design, construct, test, and evaluate a device which can successfully protect an egg from falling from greater and greater heights. No parachutes!

The final product of this project will be a *digital* engineering design challenge notebook; this one will be more extensive than our LCROSS mission.