Physics 200 Name ____________________

Collisions – Force, Impulse, and Coefficient of Restitution

In this activity you will compare two collisions between a dynamics cart and a force meter. In one case, the collision will be cushioned by the spring end of the cart. In the other, the rigid end of the cart will contact the force meter directly. You will use Logger Pro tools to measure maximum forces and impulse for both types of collision. You will also collect acceleration distance data and use those data to calculate the coefficient of restitution for each collision type.

1. Collect the necessary data to complete the table below.
2. Measure closing and separation distances from the force sensor to the nearest part of the cart (either flat edge or plunger tip, depending on the trial). *[Closing distance = distance traveled on the approach to the sensor; separation distance = distance traveled away from the sensor.]*
3. Keep the ramp slope constant for all trials, and keep the ramp firmly clamped in position.
4. Keep the closing distance constant for all trials (i.e. release the bottommost point on the cart from the same position each time).
5. Use the closing distance and the average separation distance to calculate the average coefficient of restitution.

<u>Collision Type I. Spring end of cart faces the force probe</u>

Trial	Max Force (N)	Impulse (N·s)	Linear Closing distance (cm)	Linear Separation Distance (cm)	Coefficient of Restitution
1					
2					
3					
Avg.					

<u>Collision Type II. Flat end of cart faces the force probe</u>

Trial	Max Force (N)	Impulse (N·s)	Linear Closing distance (cm)	Linear Separation Distance (cm)	Coefficient of Restitution
1					
2					
3					
Avg.					

II Questions:

A. How do the maximum forces for each collision type compare? Use the concept of impulse to explain the reason for the difference in maximum force.

Both types of collisions have similar impulses, because they cause similar changes in the momentum of the cart (i.e. it bounces back up the hill at about the same speed in both cases). However, the impact time is much shorter for the less cushioned collisions. Since impulse = Ft, in order for those uncushioned collisions to have about as much impulse as the cushioned collisions, they must have higher forces due to their shorter impact durations.

B. How do the average impulses for each collision type compare?

They are pretty similar, but usually one of them is greater than the other. Some groups find that the flat end gives a higher impulse. Some find the opposite.

D. Explain how and why coefficient of restitution and impulses are related to one another in this activity.

The collisions with the greatest coefficient of restitution should also have the greatest impulse. e = separation speed/closing speed, so a greater e means a greater change in velocity (because the cart's direction switches and speed remains high). A greater change in velocity means more change in momentum and therefore a greater impulse.

E. Without changing the cart mass, friction, slope, or closing distance, how could you decrease the impulse for each collision? How could you increase it?

Decrease or increase the coefficient of restitution. You can decrease it by introducing some friction into the collision. You could tape a crumpled piece of paper to the end of the cart. The paper would be a very bad spring in that it would not store energy and then return it during the collision. You can increase e by substituting a more efficient spring on the front of the cart.

Decrease or increase the closing distance or ramp slope. A slower cart colliding with an "immovable" object will not be able to change velocity as much (even if its separation speed and closing speed are very similar), so it will have a lower impulse. The opposite effect would be seen with faster cart.

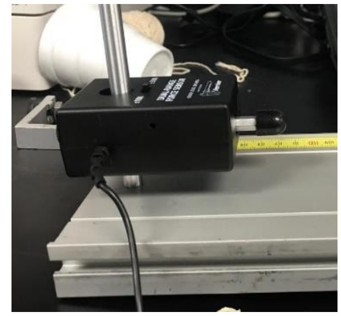
F. If you decreased the slope of the ramp slightly, what effects would you expect to see on maximum force, impulse, and coefficient of restitution?

Decreasing slope should decrease force and impulse, because the closing speed of the car will be slower, but it should not significantly change coefficient of restitution. e is, more or less, a physical property of two colliding objects – a fixed ratio of $\sqrt{KE}$ before the collision to $\sqrt{KE}$ after a collision. The ratio of KE returned during a collision should not change for a slight change in slope. Decreasing the slope would have a similar effect to releasing the cart from a closer distance, which is what

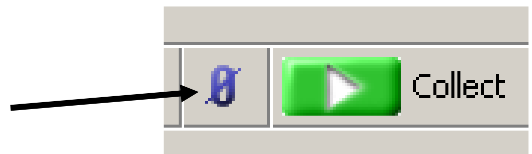
happens if you let the cart bounce repeatedly until it stops. You should see from the consistent bouncing pattern that e remains fairly constant.

However, if you change the slope A LOT, that might deform the colliding objects so much that e changes. If, for example, you increase the slope of the ramp so much that the cart plunger becomes fully compressed <u>before</u> bringing the cart to a complete stop, e will be different for that collision.

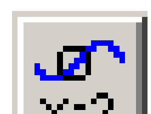
Instructions:

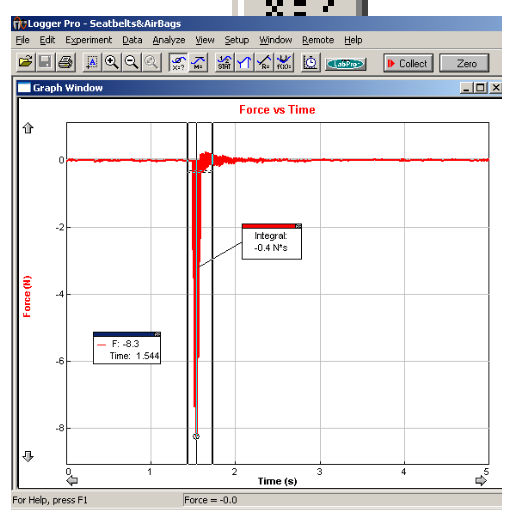


1. Connect the force sensor to Ch 1 of the LabPro Module, and connect LabPro to your computer via USB. Attach the force sensor to the track post provided (hopefully there will be a post in the box). You will need a $\frac{1}{4}$" nut to attach the post. Be sure to put it back when you're done. Make sure the end of the force sensor is centered on the middle of the cart plunger.
2. Open the newest version of Logger Pro. Then open the 50N dual range force sensor ➔ Probes & Sensors ➔ Force Sensors ➔ Dual Range 50N
3. Elevate the end of the track opposite the sensor. Placing it on a couple of books works well. Clamp the lower end securely to the lab table.
4. Zero the force probe. Remove the cart from the track and click on the zero button.

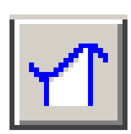


5. Place the cart near or at the uphill end of the track. Make note of the position. We are analyzing the effects of elasticity on collision forces, so all other variables (such as closing distance) need to be controlled. To truly control these other variables is tricky. Just do your best.
6. In Logger Pro, adjust the sample rate to 200 samples per second. You may also want to reduce the sampling time.
7. Click on the collect button and release the cart.
8. Find the <u>maximum force</u> of impact by using the button formerly known as the x=? button (I can't remember its current designation) and positioning the cursor on the point of the most extreme force. (Alternately, you could look through the data table to get the maximum value.) You should ignore the negative signs. We are looking for the magnitude of the force. The autoscale button may be helpful.





9. Find the <u>impulse</u> by highlighting the entire collision on the graph and clicking on the integral button. Do this with consistent care from trial to trial.



Example: Using the graph to the right.
Maximum force = 8.3 N
Impulse = 0.4 N·s = 0.4kgm/s