MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Physics Department

Momentum Demonstration

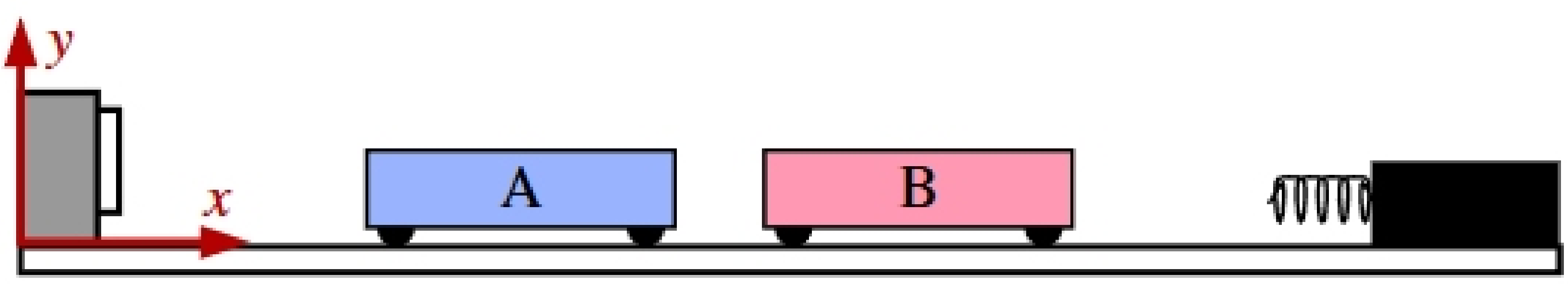
Purpose of the Experiment:

In this experiment you allow two carts to collide on a level track and run into a spring that is attached to a force sensor. You will measure the position and velocity of the first cart and the force exerted by the spring while it is compressed. You can analyze your data to determine the following things from this experiment:

- An experimental test of the conservation of momentum in elastic and inelastic collisions.
- Determination of the maximum kinetic energy that is lost to non-conservative work in a completely inelastic collision.
- You will make use of most of the ideas and computational tools that we need to analyze collisions in one dimension.

Because the track is level, we do not need to consider changes in the gravitational PE of the carts and may take it to be zero. If we consider the two carts to be an isolated system (this is a good approximation so long as the friction forces are small), the only mechanical energy is kinetic, K. A collision is *inelastic* if some of the initial K is lost to non-conservative work. A collision is elastic if no K is "lost." A collision is completely inelastic if the maximum amount of K (consistent with conservation of momentum) is converted to non-conservative work; this happens when the two colliding objects stick together. Sometimes that is what people mean when they refer simply to inelastic collisions.

Setting Up the Experiment:



- At the the end of the track with the level adjustment screw attach a force sensor with the hook replaced by the **lighter** of the two springs.
- Clip the the motion sensor to the other end of the track.
- Level your track as well as you can using the level adjustment screw. Test by making sure an empty cart does not have a tendency to roll in either direction; the test is more sensitive if you put two 250 gm weights in the cart.

The LabVIEW Program

The LabVIEW program for this experiment is *Momentum.exe*; it is very similar to the program you used last week for work/energy and the harmonic oscillator. The main pull-down menu is slightly different, with "Analyze Data" being the command to fit data or calculate the integral under a curve. Besides calculating the integral, the program can fit the functions A, $A + Bx$ or $A + Bx + Cx^2$ to the data. The position of cart A and the force on the spring are measured.

Connect the motion sensor (yellow plug into jack 1) and the force sensor to the SW750 interface. The force sensor should be plugged into channel A of the SW750. Be sure to tare the force sensor before each measurement.

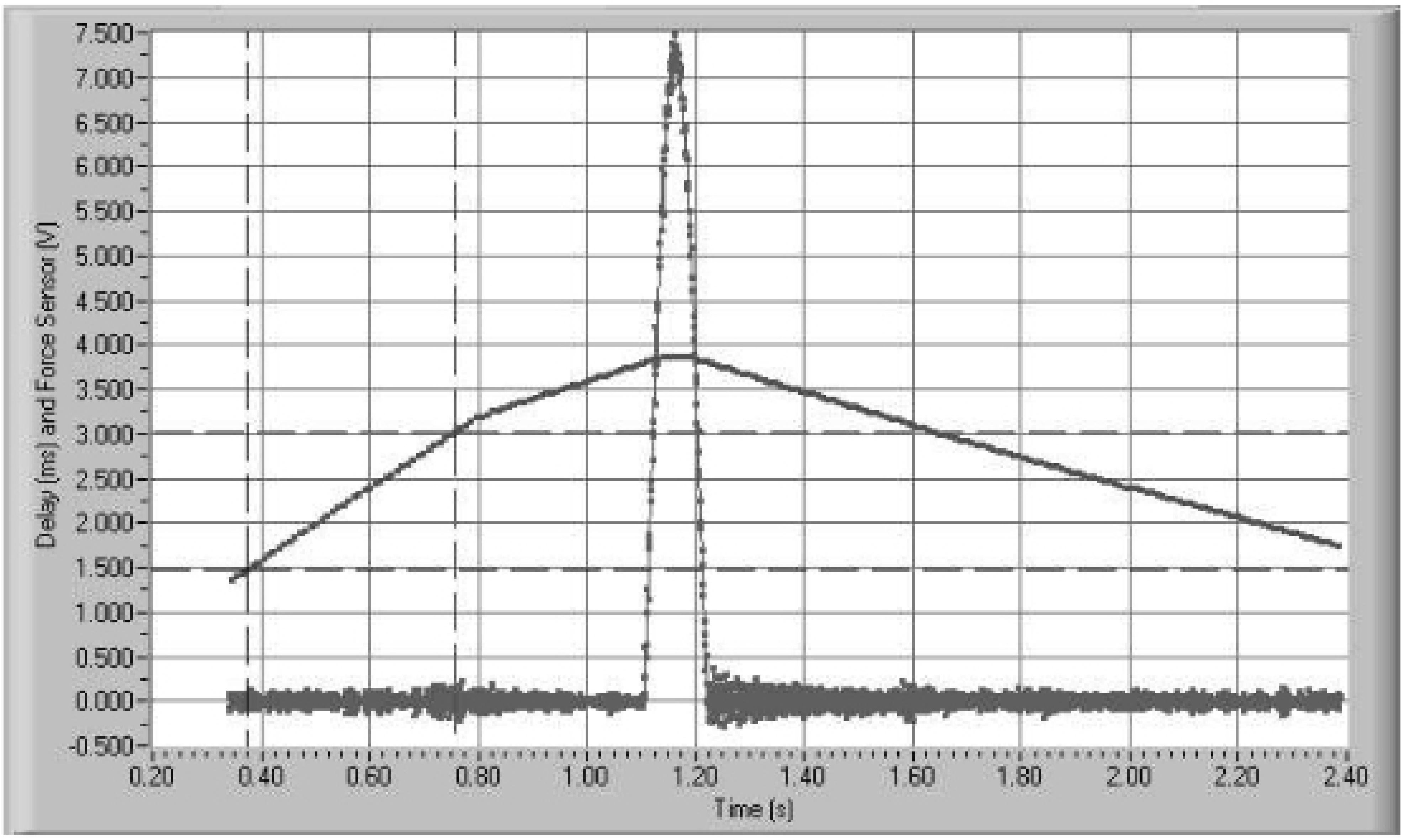
For all of the measurements set the Run Time to 10 s, the Sample Rate to 100 Hz and the Gain to 10X. When you choose Measure from the pull-down menu the RUN button changes to bright green. Clicking the button (or typing the Esc key) starts the measurement; the button will change to red and say STOP. Measurement will stop when you click the button or the Run Time has passed. While measuring the cart position and the force, the program will not actually record the data until the position crosses a trigger value of 30 cm while increasing, and recording will stop at the same trigger value with x decreasing. The normal way to make a measurement is to begin with the cart from 16 to 20 cm in front of the motion sensor, click the RUN button, and push the cart. The cart will roll at least 10 cm before data are recorded; that gives the cart time to stabilize and roll smoothly after you push it. The program will record measurements until the cart returns to the 30 cm point or the Run Time elapses.

Completely Inelastic Collisions:
You should study completely inelastic collisions first in this experiment. Place two empty carts on the track with the the Velcro pads facing each other. One cart (which I call the target cart, with mass m_B) should be placed on the track with the end with the Velcro pads about 70 cm from the motion sensor; then the other end of the cart will be about 10 cm from the spring on the force sensor. The second cart (which I will call the incident cart, with mass m_A) should be placed on the track between 16 cm and 20 cm from the motion sensor. You should push the incident cart just hard enough that it comes back to the starting point after colliding with the other cart and bouncing off the spring. If you push too hard a cart may jump during the collision, and if you push too softly cart A will not come back far enough to stop the program from taking data.

You should experiment to get this right before you start to make measurements. How hard you need push cart A changes with the masses of the two carts and whether or not the collision is inelastic, so you will have to find this out by trial and error for each of the six measurements that you make

Notation: the subscripts A and B refer to the carts, and subscripts 1 and 2 are before and after the carts collide, respectively. Make measurements with $m_\mathrm{A} = m_\mathrm{B} = 250$ gm (both carts empty), $m_\mathrm{A} = 250$ gm, $m_\mathrm{B} = 500$ gm, and $m_\mathrm{A} = 500$ gm, $m_\mathrm{B} = 250$ gm. Measure $v_{\mathrm{A},1}$ before the carts collide and $v_2 = v_{\mathrm{A},2} = v_{\mathrm{B},2}$ after the collision when the two carts are stuck together but have not yet hit the spring.

The raw data when $m_A = m_B = 0.250\,\text{kg}$ are shown in the plot below.



The best way to determine $v_{A,1}$ is to plot Position (x vs. t) and do a Linear fit to $x(t)$ before the collision. The data between the cursors will be included in the fit; there is some rounding of the x vs. t during the collision, so don't go right up to the collision with your fit.