

Impulse and Momentum Change

Your goal today is to demonstrate that impulse J gives a momentum change Δp , that is

$$J \equiv \int_{t_i}^{t_f} F(t) dt = p_f - p_i \equiv \Delta p \quad (2)$$

We will closely follow the “regular” Physics I Activity 05, which relies on Activity 03 for calibrating the force probe and for determining the effect of friction. Please refer to these activities, posted at <http://www.rpi.edu/dept/phys/Courses/phys1/activities.htm>, for details.

The experiment is done with a cart on a track. You will impart momentum to the cart by pulling on it with a force probe, which records $F(t)$. The force probe is calibrated by hanging a known mass from it. A motion sensor will determine the initial and final velocity, which you combine with the cart mass to get Δp . As always, of course, you are to try to demonstrate that both sides of Eq. 2 are satisfied to within experimental uncertainties. Friction plays a part, and you are to include its effect in order to reduce the systematic uncertainty its neglect would introduce.

(1) Debug your setup and determine the frictional force f on the cart. See Activity 03. Give the cart a push, and let friction slow it down. Measure the acceleration a with a motion sensor, so $f = ma$ where m is the mass of the cart.

(2) Calibrate the force probe. Again, see Activity 03. LOGGERPRO is apparently set up to do this automatically by hanging a known mass from it and choosing the “Calibrate” menu item. It will assume a linear response between zero and the mass you choose to hang, so you may want to try different masses.

(3) Connect the force probe to the cart, and give it a quick pull to make the cart move. (Let the cart move away from the motion sensor.) From the $F(t)$ data, identify an “initial” and “final” time over which the force acts, and calculate the integral $\int_{t_i}^{t_f} F(t) dt$. The motion sensor will give you the initial - presumably zero - and final velocity of the cart, so you can determine the change in momentum.

(4) Take into account the impulse due to friction. That is, include the term $f\Delta t$ in your calculation of the impulse. (We assume that friction is constant over the time $\Delta t = t_f - t_i$.) How big a correction does this make?

Here are some tips for getting good results:

- Make sure your track is level, otherwise gravity will be a force to be reckoned with.
- Instead of “pulling” the string, mount the force probe to the table or track. Then, send the cart away from it, attached by the string. You’ll record the “bounce” induced by the tension in the string, as well as the velocity before and after the bounce.
- Set your force probe up so that you pull on the fixture in tension only, not transversely. That is, mount the probe horizontally for measurement, and vertically for calibration. You can use a small ring stand to hold the force probe horizontally for the measurement.
- The force probe samples at ≤ 100 Hz, and the position sensor samples at ≤ 20 Hz. Use the higher sampling rate of the force probe to your advantage, to get a more accurate integral of $\int F(t) dt$. Set the sampling rate under the “Experiment” \Rightarrow “Data Collection” menus in LOGGERPRO.