Measuring Impulse and Momentum Change in 1 Dimension – Concepts

DISCUSSION OF PRINCIPLES

This document is largely for N students. This week's lab should be a very straightforward application of the Momentum Principle for M students, but may not be as familiar for N students. The following very briefly covers the main ideas.

Momentum Principle

First, we will define a useful physical concept known as momentum, a quantity related to an object's motion and inertia. At speeds not close to the speed of light, momentum is defined as

$$\mathbf{p} = m\mathbf{v}, \tag{1}$$

where $\mathbf{p}$ is the object's momentum, m is its mass, and $\mathbf{v}$ is its velocity.

One of the most-used equations in your N course will be Newton's 2nd Law, which you will get to very soon if you haven't already. It's typically expressed as

$$\mathbf{F}_{\text{net}} = m\mathbf{a}, \tag{2}$$

where $\mathbf{F}_{\text{net}}$ is the vector sum of all forces acting on a particular object, m is the object's mass, and $\mathbf{a}$ is the acceleration of the object resulting from the net force. Recalling that the instantaneous velocity of an object can be defined as $\mathbf{a} = \dfrac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$ and the average velocity can be defined as $\mathbf{a}_{\text{ave}} = \dfrac{\Delta\mathbf{v}}{\Delta t}$, we see that we can easily re-express equation 2 as

$$\mathbf{F}_{\text{net}} = m\frac{\mathrm{d}\mathbf{v}}{\mathrm{d}t} \tag{3}$$

or

$$\mathbf{F}_{\text{net, ave}} = m\frac{\Delta\mathbf{v}}{\Delta t}. \tag{4}$$

For situations with a constant net force, Newton's 2nd Law tells us that the acceleration must also be constant, and so equation 4 can simply be written as

$$\mathbf{F}_{\text{net}} = m\frac{\Delta \mathbf{v}}{\Delta t} = \frac{\Delta(m\mathbf{v})}{\Delta t}. \tag{5}$$

Since we've defined momentum as $\mathbf{p} = m\mathbf{v}$, this becomes

$$\mathbf{F}_{\text{net}} = \frac{\Delta \mathbf{p}}{\Delta t}, \tag{6}$$

an alternative formulation of Newton's 2nd Law, and the equation known as the Momentum Principle in the M course. This will be the main equation used in the lab today.