Lab: Impulse & Momentum — AP Physics

Background:

Newton's Second Law of Motion is often stated as $\mathbf{F}_{net} = m\mathbf{a}$: a given net Force applied to a mass causes it to accelerate. This equation can be rearranged to give $\int \mathbf{F} \bullet dt = m\Delta\mathbf{v}$, which is sometimes called the "impulse form" of the equation, where the impulse $\int \mathbf{F} \bullet dt$ acting on a body to the exclusion of all else produces a change in the momentum $m\Delta\mathbf{v}$ of the body.

Additionally, if two objects collide in a "closed system," their collision forces will be action-action pairs (equal and opposite a la Newton's Third Law of Motion). Because these forces act over identical times, the *impulse* each produces on the other will be equal and opposite, which leads us to the Law of Conservation of Momentum:

$$m_1\mathbf{v}_{1i} + m_2\mathbf{v}_{2i} = m_1\mathbf{v}_{1f} + m_2\mathbf{v}_{2f}$$

Complications arise if "outside" (external) forces are acting during such collisions, but for this lab, we will assume that isn't happening.

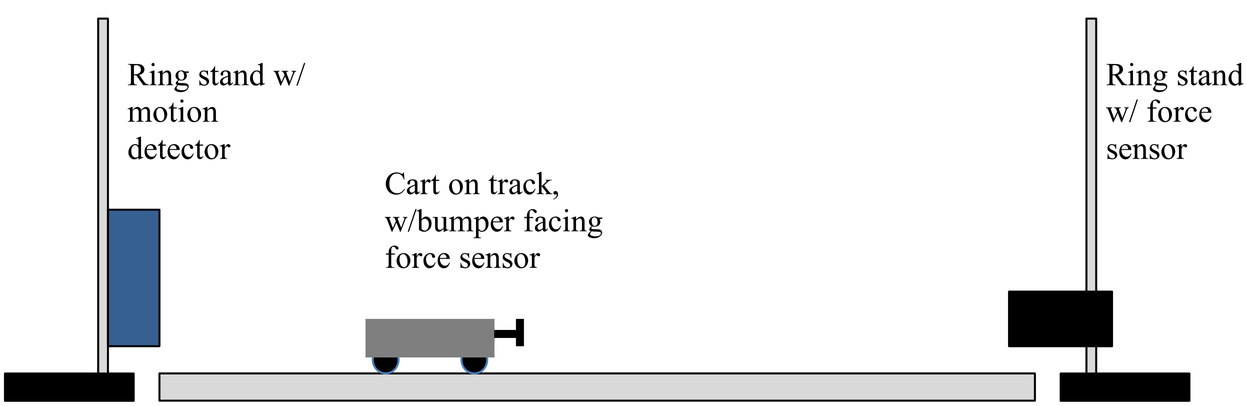
You will be working here with two different lab set-ups, each of which will provide data for relatively friction-free environments. One will be a low-friction glider on a one-dimensional track colliding with a force transducer, and the second will use transponders to track three low-friction gliders colliding with each other on a one-dimensional track.

Objectives:

To experimentally determine if impulse $\int \mathbf{F} \bullet dt$ from an external force produces a corresponding change in momentum $m\Delta\mathbf{v}$ in a collision, and to use conservation of momentum to analyze the hypothetical collision of three carts.

Equipment:

Part A: Low-friction cart, metal track, motion detector and force transducer connected to LabPro unit, and a balance. The set-up is shown below.



Procedure/Data Taking:

Part A: ***Does Impulse = Change in Momentum?***

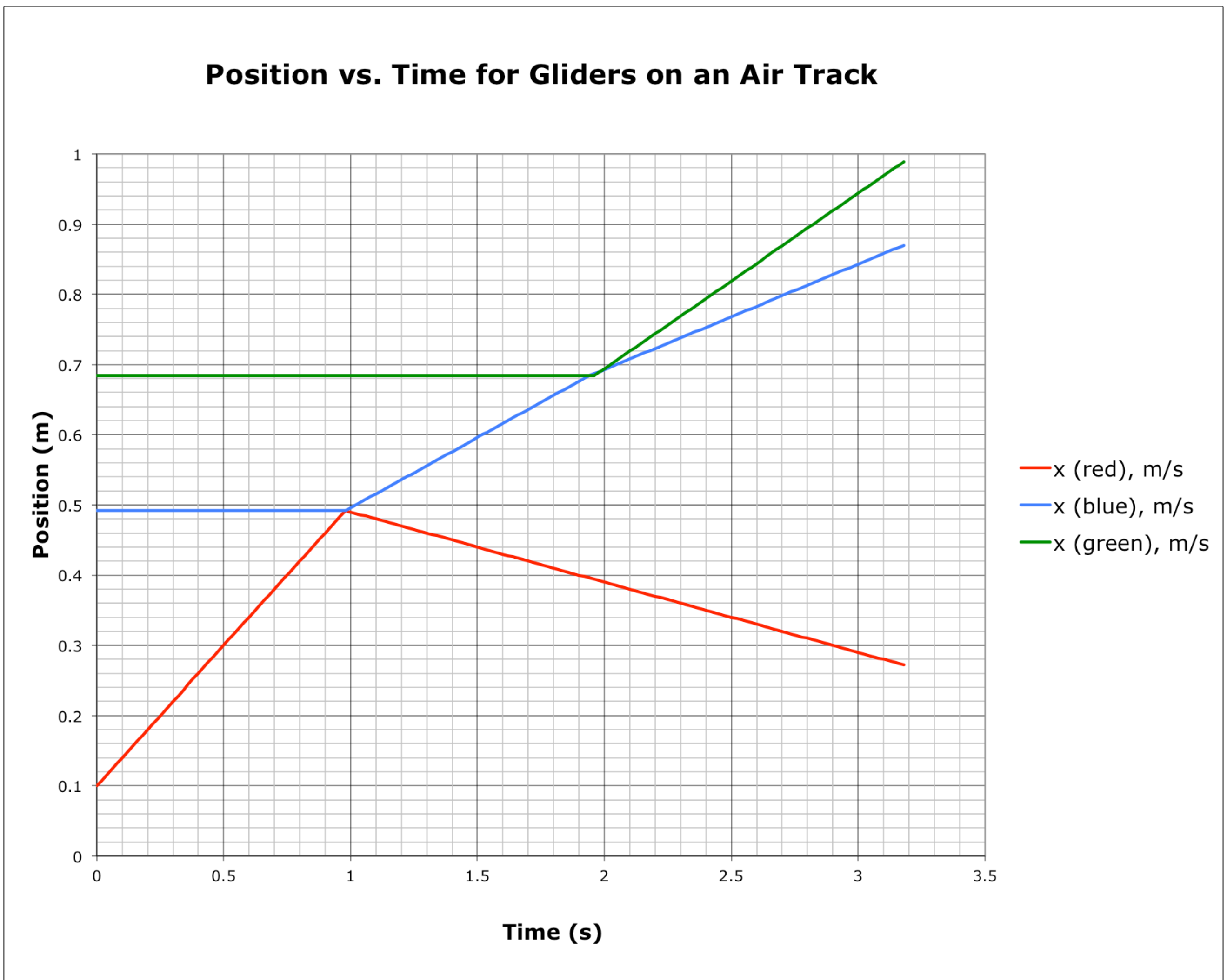
Look at the video at https://youtu.be/bkNx4mlhQk4 for this part of the experiment. All the data you will need to do this part of the write-up will be provided there. You should find data that will yield:

a. $\int \mathbf{F} \bullet dt$ data that will allow you to determine the impulse applied to your moving cart (this will be the area under the *force vs time* graph), and

b. $m\Delta\mathbf{v}$ data that will allow you to calculate the resulting change in momentum of the cart.

Part B: *(conservation of momentum and three-gliders on a linear track colliding sequentially)*

2. Three gliders (a blue one, a red one and a green one) on a linear track collide sequentially (the blue and red ones collide, then the blue and green ones collide). A transponder on each glider allows us to produce a graph that tracks each glider's position as a function of time (see below). Given the individual glider masses (also provided below) and the information provided on that *position-vs.-time* graph, describe what is happening *qualitatively* throughout the gliders' motions, then verify *quantitatively* that momentum is conserved.



mass of red glider (kg)	0.200 kg
mass of blue glider (kg)	0.500 kg
mass of green glider (kg)	0.100 kg

Questions:

1. For your data from Part A, give quantitative evidence where possible to support your answers to the questions below. Distinguish between stating that a quantity was conserved "because it's a law," and citing your results as evidence that a quantity is or isn't conserved.
   - Was momentum conserved during the collision?
   - Did impulse correspond to any change in momentum during the collision?
   - Was energy conserved during the collision (this may be a trick question—be careful)?
   - Was kinetic energy (mechanical energy) conserved during the collision?

2. For your graphical analysis of the chart in Part B, give quantitative evidence where possible to support your answers to the questions below. Distinguish between stating that a quantity was conserved "because it's a law," and citing your results as evidence that a quantity is or isn't conserved.
   - Was momentum conserved throughout?
   - Was energy conserved throughout?
   - Was kinetic energy conserved throughout?

Additional Notes

- Although it isn't mentioned specifically in the lab protocol here, you'll want to make sure that you both *calibrate* and *zero* your measuring devices, where possible. *Calibrating* a piece of equipment consists of using a known measurement to ensure that the measuring device reads correctly that measurement. (If a Force sensor indicates that a 30.0 N force is really 35.0 Newtons, that's going to be a problem.) Likewise, the measuring device needs to be *zeroed*, so that it reads "0" when appropriate. (If a Force sensor indicates 0.50 N when there is no force being applied, that's *also* going to be a problem.) Where possible, check to see that your measuring devices have been calibrated and zeroed.

- In Part A, you'll be collecting data from several different sources: your own measurements, the motion detector's velocities, the force sensor's readings... Make sure you leave plenty of space in your lab entry for your data tables, and for taping in the Force vs. time graph that LoggerPro will print out for you.

- In Part A, LoggerPro will automatically determine Impulse for you, if you tell it to. Give some thought as to what you should have it display in order to reveal that information, and make sure that data gets printout out along with your graphs!

- The low-friction cart has a spring-bumper that interacts with the spring in the force sensor to produce some very interesting oscillations in the Force-time graph. It's an interesting to question whether this is a source of experimental uncertainty, or if the data collected is just fine for performing our analysis.