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 $\int \mathbf{F} \bullet dt$ produced by an external force on a non-closed system causes a change in momentum $m\Delta\mathbf{v}$.

If two objects collide in a "closed system," they exert equal magnitude forces in opposite directions on each other, as described by Newton's Third Law of Motion. Because these forces act over identical times, it's clear that the *impulse* the objects exert each other must be the same, leading us to the Law of Conservation of Momentum:

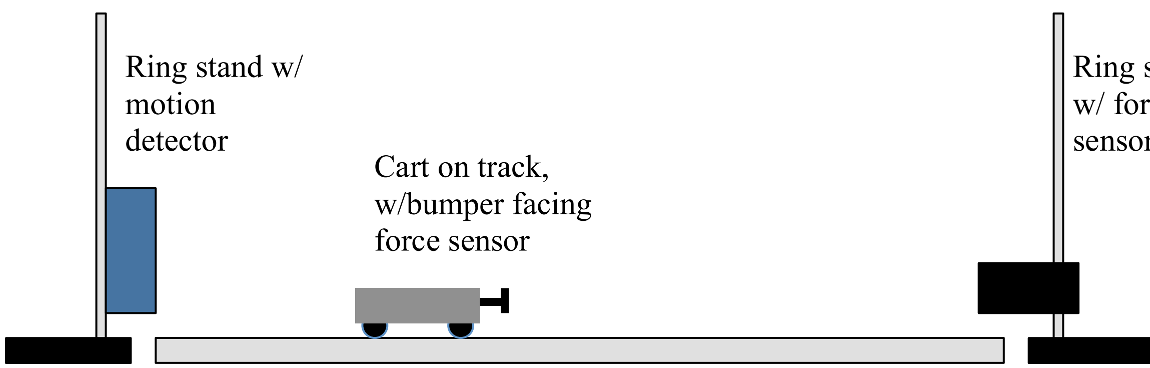
$$m_1\mathbf{v}_{1i} + m_2\mathbf{v}_{2i} = m_1\mathbf{v}_{1f} + m_2\mathbf{v}_{2f}$$

Although there may be other forces acting on the objects in questions, in a closed-system analysis the effect of those other forces is considered negligible.

There are two different lab set-ups that allow us to collect data in relatively friction-free environments. In one, a type of one-dimensional "air hockey" track allows a metal glider to travel along it, floating on a cushion of air. In the second, used in our experiment, low-friction carts travel along a metal track.

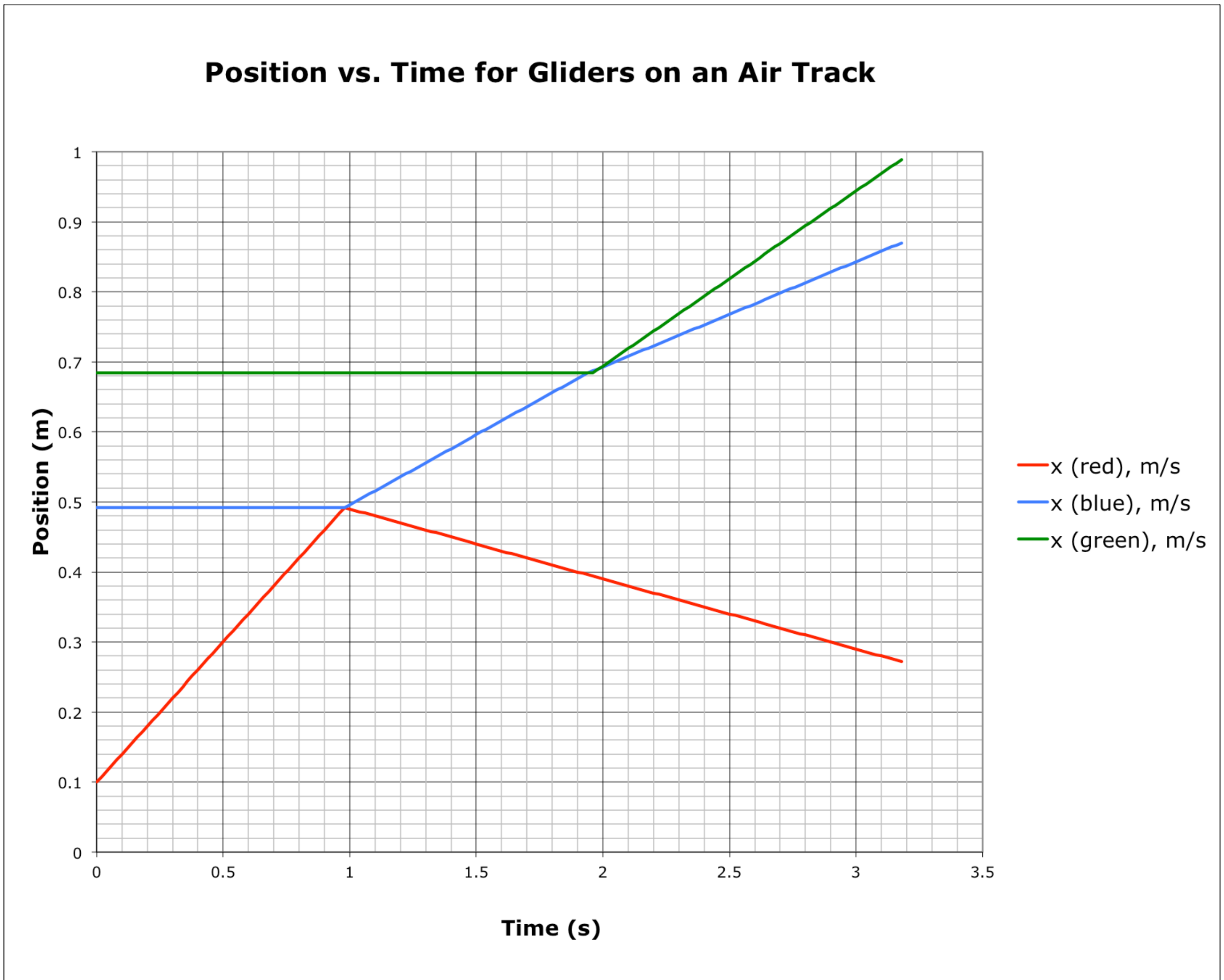
Objectives
To experimentally determine if impulse $\int \mathbf{F} \bullet dt$ from an external force produces a corresponding change in momentum $m\Delta\mathbf{v}$ in a collision, and to use conservation of momentum to analyze the hypothetical collision of three carts.

Equipment
For Part A: Low-friction cart, metal track, motion detector and force probe connected to LabPro unit, balance
For Part B: Graph of motion data included here



Procedure

Part A. Does Impulse = Change in Momentum?
1. Set up the equipment as shown in the diagram, with motion detector and force sensor plugged into Lab Pro.
2. Start up Logger Pro on the computer. Force-time and motion-time graphs should display on the monitor.
3. Practice collecting data with the equipment until you have a good run that clearly shows:
    a. $\int \mathbf{F} \bullet dt$ data that will allow you to determine the impulse applied to a moving cart, and
    b. $m\Delta\mathbf{v}$ data that will allow you to calculate the resulting change in momentum of the cart.
4. Print a hard copy of your data that can be used in your analysis and submitted with your lab report.



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

Part B. Conservation of Momentum
The graph given here shows position-vs.-time data for three objects—a red cart, a green cart, and a blue cart—all traveling along the *x*-axis. Use the information on the graph to describe what is happening qualitatively throughout the gliders' motions, and verify quantitatively that momentum is conserved.

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?
   - Was kinetic 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?

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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.