Experiment 3: Momentum

Table and Group: _______ Participants: ________________________________
Each group will turn in one common report. ______________________________

In all parts, $m_1$ refers to the incoming moving cart, $m_2$ refers to the initially stationary cart, $v_0$ refers to the initial velocity of the incoming cart, $v_1$ is the velocity of $m_1$ (and also $m_2$ in the inelastic collision) after the collision. The cart masses are 0.25 kg plus any additional weights used. Include the units on all quantities and make sure to be consistent.

Part One: Impulse and Change in Momentum: bouncing a cart from a spring
Investigate the prediction that $\vec{p}_{\text{final}} - \vec{p}_{\text{initial}} = m_1 \vec{v}_1 - m_1 \vec{v}_0 = \int \vec{F} \, dt$. Pay attention to the signs, the direction away from the motion sensor is defined to be positive.

Measure: Cart mass=__________ (carts are 0.25 kg, plus any added weights)
Velocity before hitting spring=__________ Velocity after hitting spring=__________

Calculate: Change in momentum $(\vec{p}_{\text{final}} - \vec{p}_{\text{initial}}) =$

Measure: Integral of force versus time=__________
Interpretation: Do the magnitude and sign of your $\Delta \vec{p}$ and $\int \vec{F} \, dt$ appear to agree?

Part Two: Inelastic Collisions: carts collide and stick together
Compare momentum before and after an inelastic collision: $\vec{p} = m_1 \vec{v}_0 = (m_1 + m_2) \vec{v}_1$.

Measure: Incoming cart mass ($m_1$) =__________ (0.25 kg plus added weights)
Struck cart mass ($m_2$) =__________ Mass of carts combined =__________
Velocity before collision ($v_0$) =__________ After collision ($v_1$) =__________

Calculate: Initial momentum=__________ Final momentum=__________
Interpretation: Do the magnitude and sign of your $m_1 \vec{v}_0$ and $(m_1 + m_2) \vec{v}_1$ appear to agree?
Part Three: Elastic Collisions: carts collide and fly apart

Investigate the prediction that the velocity of the incoming cart after an elastic collision is
\[ v_1 = \frac{m_1 - m_2}{m_1 + m_2} v_0. \]
Be careful of the signs of the velocity before and after the collisions, the direction away from the motion sensor is defined to be positive.

Part ThreeA: Incoming cart lighter \((m_1 < m_2)\)

Incoming cart mass \((m_1)\) =  
Struck cart mass \((m_2)\) = 
Velocity of \(m_1\) before collision = 
Velocity of \(m_1\) after collision = 

Calculate: Predicted outgoing velocity = 
Interpretation: Do your data appear to support the prediction (magnitude and sign)?

Part ThreeB: Incoming cart heavier \((m_1 > m_2)\)

Incoming cart mass \((m_1)\) =  
Struck cart mass \((m_2)\) = 
Velocity of \(m_1\) before collision = 
Velocity of \(m_1\) after collision = 

Calculate: Predicted outgoing velocity = 
Interpretation: Do your data appear to support the prediction (magnitude and sign)?

Optional: Additional analysis of elastic collision

In the elastic collisions, the struck cart rebounds off of the spring. As you did above, you can use the integral of the force versus time plot to find the change in momentum of the cart. Under the assumption that the cart hits and rebounds with the same speed (which you can evaluate and perhaps correct for using your data from Part One of this experiment), the impulse can be used to calculate the speed from:
\[ \int F \, dt = 2m_2 v_2. \]
Measuring this impulse allows you to calculate the velocity of the struck cart after the collision.

Integral of force versus time =  
Calculate: Speed of \(m_2\) after collision = 

While the carts were colliding, did the total momentum change?  
While the carts were colliding, did the total kinetic energy change?