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PH – 1110 – CX16

Impulse and Momentum

Question: 1

Include your working and commented python code OR clearly written math for the uncertainty if you decided to do this by hand for the propagation of uncertainty. Using the uncertainty on the mass and velocity, please find a final uncertainty on the differences in momentum.

```
In [1]: ### Slow trial

        ### 1: velocity
        v_Ai = 0.4021 #initial velocity
        dv_Ai = 0.00163  #uncertainty of velocity
        v_Af = -0.3738 #final velocity
        dv_Af = 0.0038  #uncertainty of "
        delta_vA = v_Af - v_Ai #change in velocity
        dvA = dv_Ai + dv_Af #propogation of uncertainty for velocity
        ### 2: mass
        m = 0.50051 #measured mass of the cart in kg
        dm = 0.00005 #uncertainty in "

        ### 3: momentum
        p_0 = (m * v_Ai) #initial momentum of the system
        dp_0 = p_0 * ((dm/m)+((dv_Ai)/abs(v_Ai))) #uncertainty in "
        #Some notes on the above equation
        #Don't need to do absolute value of m
        #because it's already positive
        p_f = (m * v_Af) #final momentum of the system
        #uncertainty in momentum
        dp_f = p_f * ((dm/m)+((dv_Af)/abs(v_Af)))
        delta_p = p_f - p_0 #change in momentum
        dp = dp_f + dp_0 #uncertainty of "
        print("change in momentum:",delta_p,"±",dp," kg * m/s")
        #print the change in momentum and its uncertainty
```

(Figure: 1 – Python Code – 1)

$$The\ change\ in\ momentum\ is\ -0.184437935\ \pm\ -0.093279414\ Kg * m/s$$

```python
### Slower trial

### 1: velocity
v_Ai = 0.3333 #initial velocity
dv_Ai = 0.00162  #uncertainty of velocity
v_Af = -0.3032 #final velocity
dv_Af = 0.0028  #uncertainty of "
delta_vA = v_Af - v_Ai #change in velocity
dvA = dv_Ai + dv_Af #propogation of uncertainty for velocity
### 2: mass
m = 0.50051 #measured mass of the cart in kg
dm = 0.00005 #uncertainty in "

### 3: momentum
p_0 = (m * v_Ai) #initial momentum of the system
dp_0 = p_0 * ((dm/m)+((dv_Ai)/abs(v_Ai))) #uncertainty in "
#Some notes on the above equation
#Don't need to do absolute value of m
#because it's already positive
p_f = (m * v_Af) #final momentum of the system
#uncertainty in momentum
dp_f = p_f * ((dm/m)+((dv_Af)/abs(v_Af)))
delta_p = p_f - p_0 #change in momentum
dp = dp_f + dp_0 #uncertainty of "
print("change in momentum:",delta_p,"±",dp," kg * m/s")
#print the change in momentum and its uncertainty
```

(Figure: 2 – Python Code – 2)

$$The\ change\ in\ momentum\ is\ -0.31857461500000006 \pm -0.0005890968000000001\ Kg * m/s$$

Question: 2 – Experimental Method

In complete sentences, communicate the steps that you took when collecting and analyzing your data. Pretend you are writing this so a fellow student that missed this lab could take and analyze the data using only this section. For example, you do not need to tell them to press start in Logger Pro or open the program, but you would want to tell them what sensors you used to collect data and the setting to use on the force sensor.

1. *For the experiment, we set up the Vernier Motion Detector, Vernier Dynamics Cart, Vernier Dual-Range Force Sensor, Vernier Hoop Bumper, Flat Cart Track, and Mass Balance.*

2. *We verified that the range selection switch was in the 10N position and that the force sensor was zeroed. Additionally, we made adjustments to the motion sensor to ensure that it accurately detected cart motion throughout the track's full range of motion.*
3. *Three separate versions of the experiment were run, with the cart moving at various speeds when it hit the force sensor's hoop bumper. The speeds were progressively slower. Throughout the experiment, we made sure that the hoop bumper never entirely compressed, and we saved the data after each trial.*
4. *The force delivered to the cart over time was measured using a force sensor for each trial, while the cart's location and movements were tracked using motion sensors. With the mass balance, we also calculated the cart's mass.*
5. *We analyzed the data using the integral fit tool in Logger Pro to numerically measure the area under the curve for the force vs. time graph. We used this area to calculate the impulse of the force applied to the cart over time.*
6. *Using the velocity data, we calculated the change in momentum of the cart before and after the force was applied using the equation mv2 - mv1. We then compared this change in momentum to the impulse calculated in step 5 using the equation.*

$$mv_2 - mv_1 = \int t_2 - t_1 \, F(t)dt$$

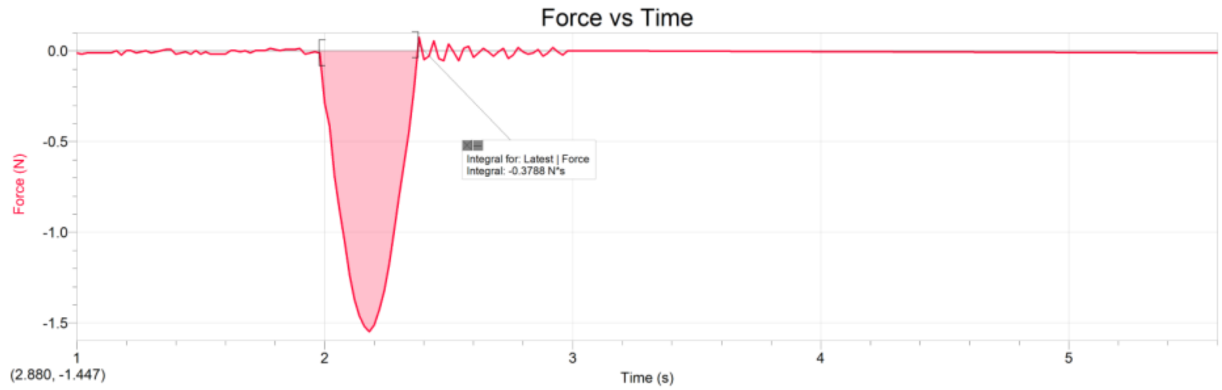
7. *We repeated steps 3-6 for each variation of the experiment and recorded all of our data and calculations in a lab report.*

Question: 3 – Results

Report the results of your experiment in complete sentences using your calculated numbers, you should also include you numbers in table. At minimum, your table should have the following columns: Trial Number, Type of motion (Slow, Slower, Slowest), Impulse and Change in momentum. Don't forget to include units and significant figures.

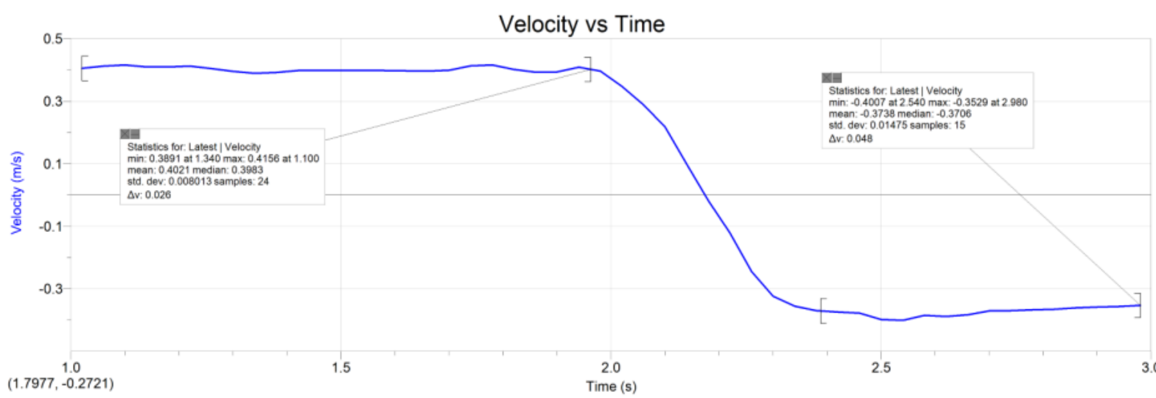
You should place your graphs with captions in this section as well.

Trial: 1 – Slow



(Figure: 3 – Force vs Time - Slow)

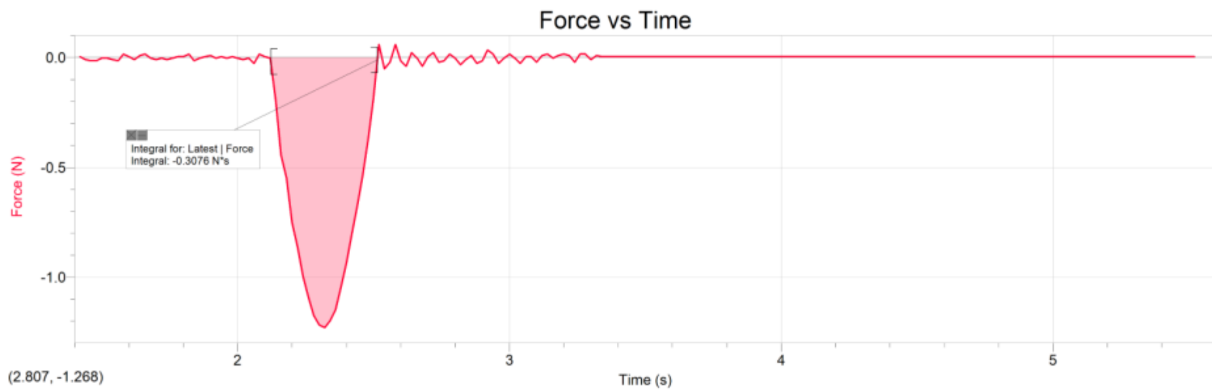
The graph illustrates the shift in force at the time of impact. By applying the formula $F \times \Delta T = m \times \Delta v$*, we can derive the impulse from the region beneath the graph showcasing the relationship between Force and Time.*



(Figure: 4 – Velocity vs Time - Slow)

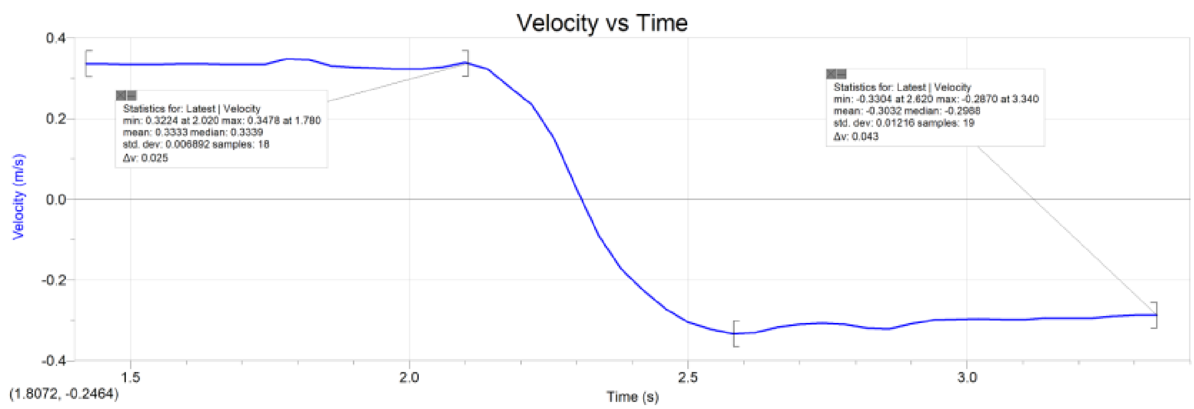
The chart displays an object that moves towards the point of impact with a steady speed and then reverses direction with a lower final velocity. As the object undergoes impact, some of its energy will be expended, resulting in a reduction in velocity from its initial value. The dissimilarity between the initial and final velocities is the result of vector addition and can be employed to compute the change in momentum, which is equal to the product of mass and velocity difference, $\Delta P = m \times \Delta v$

Trial: 2 – Slower



(Figure: 5 – Force vs Time - Slower)

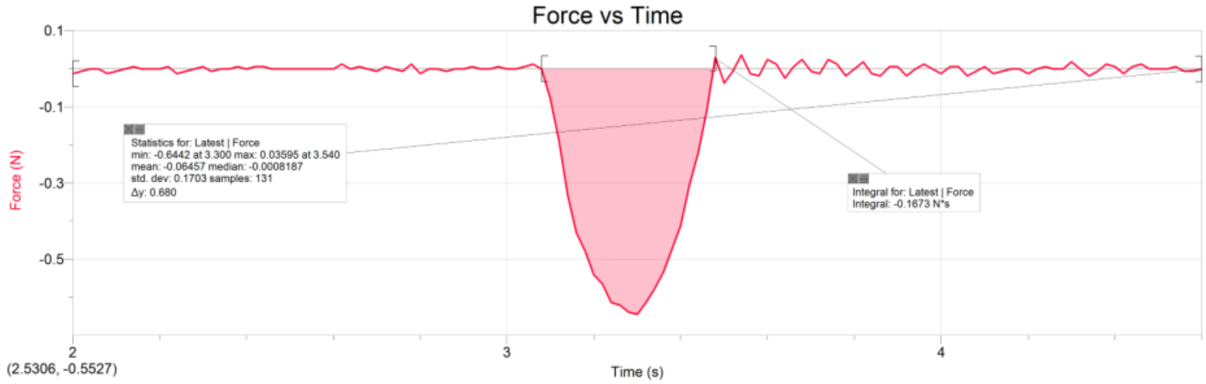
The graph illustrates the shift in force at the time of impact. By applying the formula $F \times \Delta T = m \times \Delta v$*, we can derive the impulse from the region beneath the graph showcasing the relationship between Force and Time.*



(Figure: 6 – Velocity vs Time - Slower)

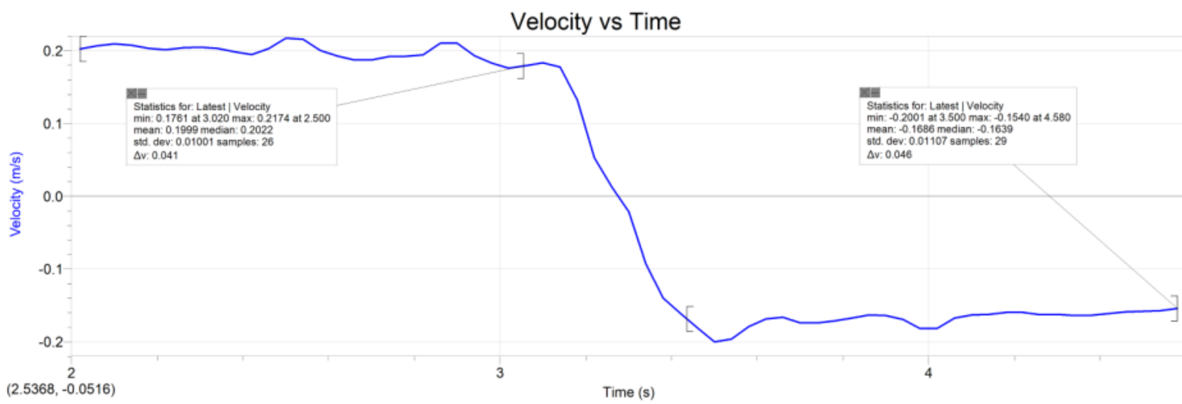
The chart displays an object that moves towards the point of impact with a steady speed and then reverses direction with a lower final velocity. As the object undergoes impact, some of its energy will be expended, resulting in a reduction in velocity from its initial value. The dissimilarity between the initial and final velocities is the result of vector addition and can be employed to compute the change in momentum, which is equal to the product of mass and velocity difference, $\Delta P = m \times \Delta v$

Trial: 3 – Slowest



(Figure: 7 – Force vs Time – Slowest)

The graph illustrates the shift in force at the time of impact. By applying the formula $F \times \Delta T = m \times \Delta v$*, we can derive the impulse from the region beneath the graph showcasing the relationship between Force and Time.*



(Figure: 8 – Velocity vs Time – Slowest)

The chart displays an object that moves towards the point of impact with a steady speed and then reverses direction with a lower final velocity. As the object undergoes impact, some of its energy will be expended, resulting in a reduction in velocity from its initial value. The dissimilarity between the initial and final velocities is the result of vector addition and can be employed to compute the change in momentum, which is equal to the product of mass and velocity difference, $\Delta P = m \times \Delta v$

Type of Motion	Slow	Slower	Slowest
Impulse $kg\ (m/s)$	-0.3788	-0.3076	-0.1673
Initial Velocity $kg\ (m/s)$	0.4021	0.3333	0.1999
Initial Velocity Uncertainity	0.00163	0.00162	196
Final Velocity $kg\ (m/s)$	-0.3738	-0.3032	-0.1686
Final Velocity Uncertainity	-0.3738	-0.3032	-0.1686
Mass of Cart kg	0.50051	0.50051	0.50051
Uncertainty of the Mass kg	0.00005	0.00005	0.00005
Change in Momentum $kg\ (m/s)$	-0.3883	-0.3186	-0.1844
Uncertainty of Change in Momentum	0.0028	0.0006	0.0093

(Table: 1 – Data Table for Slow, Slower, and Slowest)

Question: 4 – Conclusion

Write a sentence or two for each question asked below. Back up your conclusions with evidence. For example, use equations, measurements, references to figures, etc, when appropriate.

Based on your results listed above, does the change in momentum equal the impulse within your measured and calculated uncertainty (Include your numbers)?

•Does your conclusion hold true for the different speed collisions?

Based on the results listed above, the impulse calculated from the integral is not within the measured uncertainty limits for any of the three collision speeds. However, the errors are relatively small, ranging from 1.7% to 10.2%. This suggests that the change in momentum approximately equals the impulse within the measured and calculated uncertainty.

•If so, what might be an interesting extension to this experiment?

An interesting extension to this experiment might be to explore how the masses of the objects involved in the collisions affect the relationship between impulse and change in momentum.

•If not, what change to your experiment might help you get better results.

To improve the results of the experiment, higher speeds could be used, as the percentage errors were found to be smaller at higher speeds. Additionally, using more precise measurement equipment or repeating the experiment multiple times could help to reduce the overall uncertainty.