Physics Laboratory Report

Lab number and Title: Lab 126 – Conservation of Linear Momentum and Impulse (Momentum Theorem)

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Course & Section Number: PHYS111A - 011 **Instructor's Name: Professor Thuan Nguyen**

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1. INTRODUCTION

1.1 Objectives

In this lab, we learned and applied our understanding of a new concept of momentum and impulse. We were provided a system with a platform at equilibrium and two gliders, and in the series of experiments, we had to apply our understanding of momentum and impulse. Our objective today was to implement the formulas learned in class and relate them to previously learned concepts such as the conservation of energy, various definitions/laws in regard to forces, and the relationship between mass and velocity.

1.2 Theoretical background

In order for us to do this experiment, we need to have a base understanding of what momentum and impulse really are. Momentum represents an objects desire to remain in motion or at rest, and is represented mathematically by p = mv, where p is momentum, m is the mass, and v is velocity. This is pretty similar to what kinetic energy is (because kinetic energy also uses m and v), but is the derivative of the kinetic energy formula. The second portion is with impulse, or the change in momentum. There is three formulas to know for this one. The first is J = p2 – p1, where J is the impulse, p2 is the final momentum, and p1 is the initial. This is derived from the definition of impulse. The next one is $J = F_{avg}*t$, where J is the impulse, F_{avg} is the average force applied, and t is the time. This is for a constant force, or when you want to take the average force that's been applied. The changed version of this is J = integral(F(t) dt, where J is the impulse and F(t) is a function of force as it relates to time. We have to take the integral of two points to get the answer.

2 EXPERIMENTAL PROCEDURE

Part One

We used the same procedure as the manual instructed with one exception. The circular bands used to bounce between the two gliders was replaced with rubber bands.

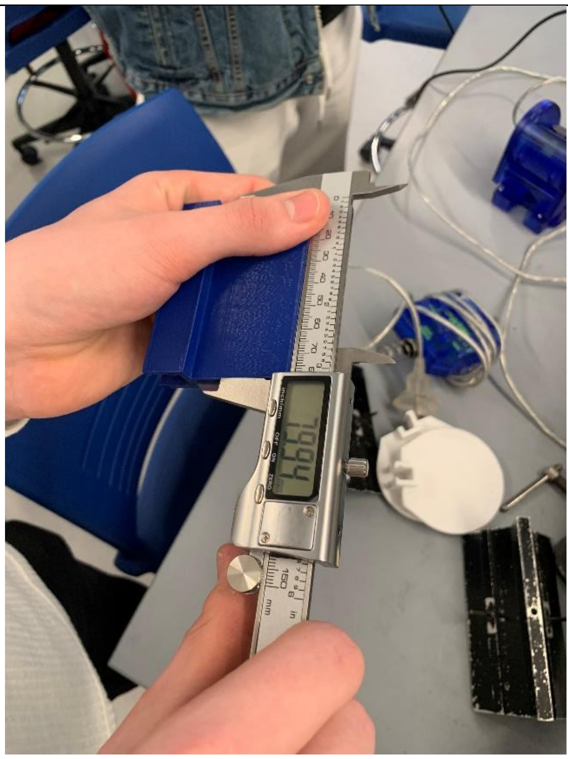
Mass of M1 (0.21156 kg)

Mass of M2 – no extra weight (.21173 kg)

Mass of M2 – 2 extra weights (.31152 kg)

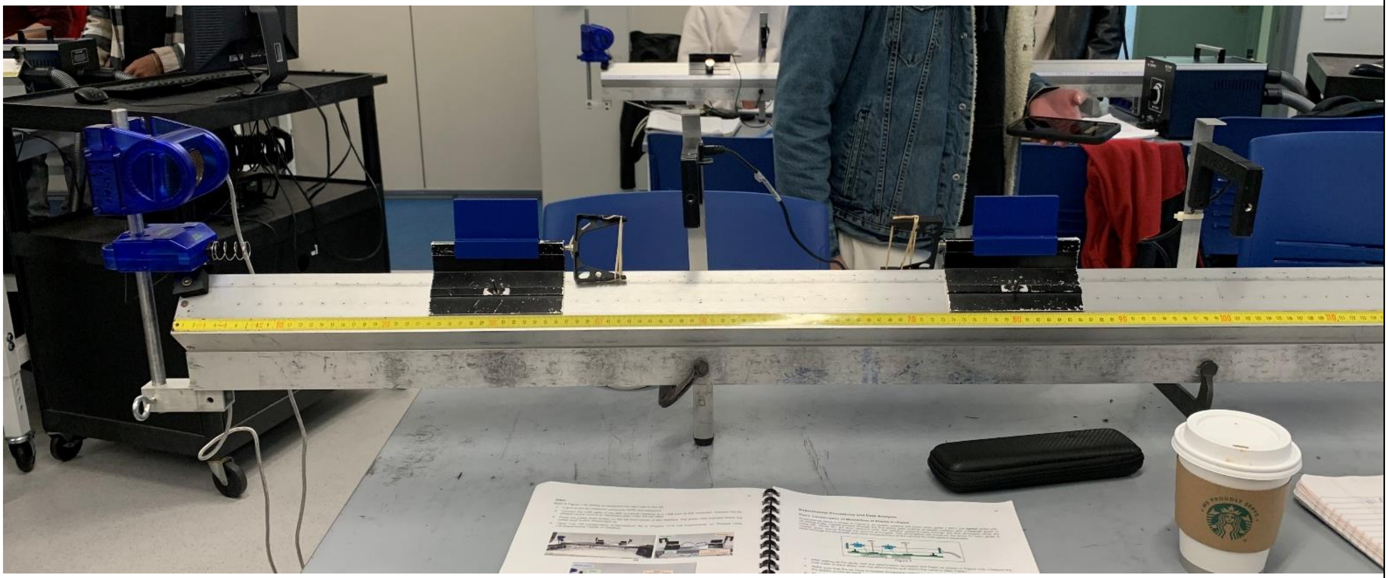
Mass of M2 – 4 extra weights (.41121 kg)

Length of Glider 1 (7.985cm)



Length of Glider 2 (7.994cm)

Experimental Setup



Variables

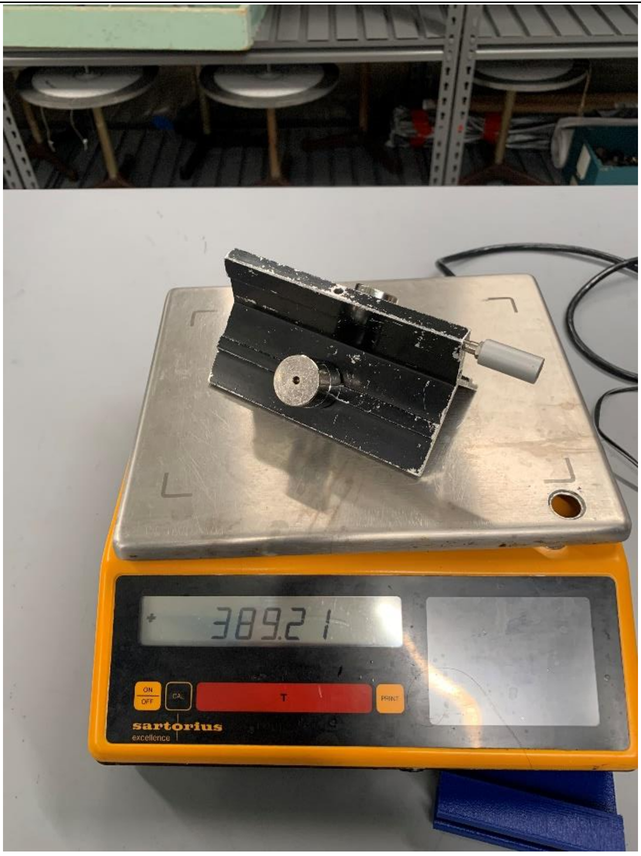
- Mass of Glider 1 (m1)
- Mass of Glider 2 (m2)
    - The value of mass changes for each run.
- Velocity of Glider 1 Before Contact (V1)
- Velocity of Glider 2 Before Contact (V2)
- Velocity of Glider 1 After Contact (V1’)
- Velocity of Glider 2 After Contact (V2’)
- Momentum of Glider 1 Before Collision (p1)
- Momentum of Glider 2 Before Collision (p2)
- Momentum of Glider 1 After Collision (p1’)
- Momentum of Glider 2 After Collision (p2’)
- Total Momentum Before Collision (p_{total})
- Total Momentum After Collision (p_{total}’)
- Kinetic Energy of Glider 1 Before Collision (KE1)
- Kinetic Energy of Glider 2 Before Collision (KE2)
- Kinetic Energy of Glider 1 After Collision (KE1’)
- Kinetic Energy of Glider 2 After Collision (KE2’)
- Total Kinetic Energy Before Collision (KE_{total})
- Total Kinetic Energy After Collision (KE_{total}’)

Part Two

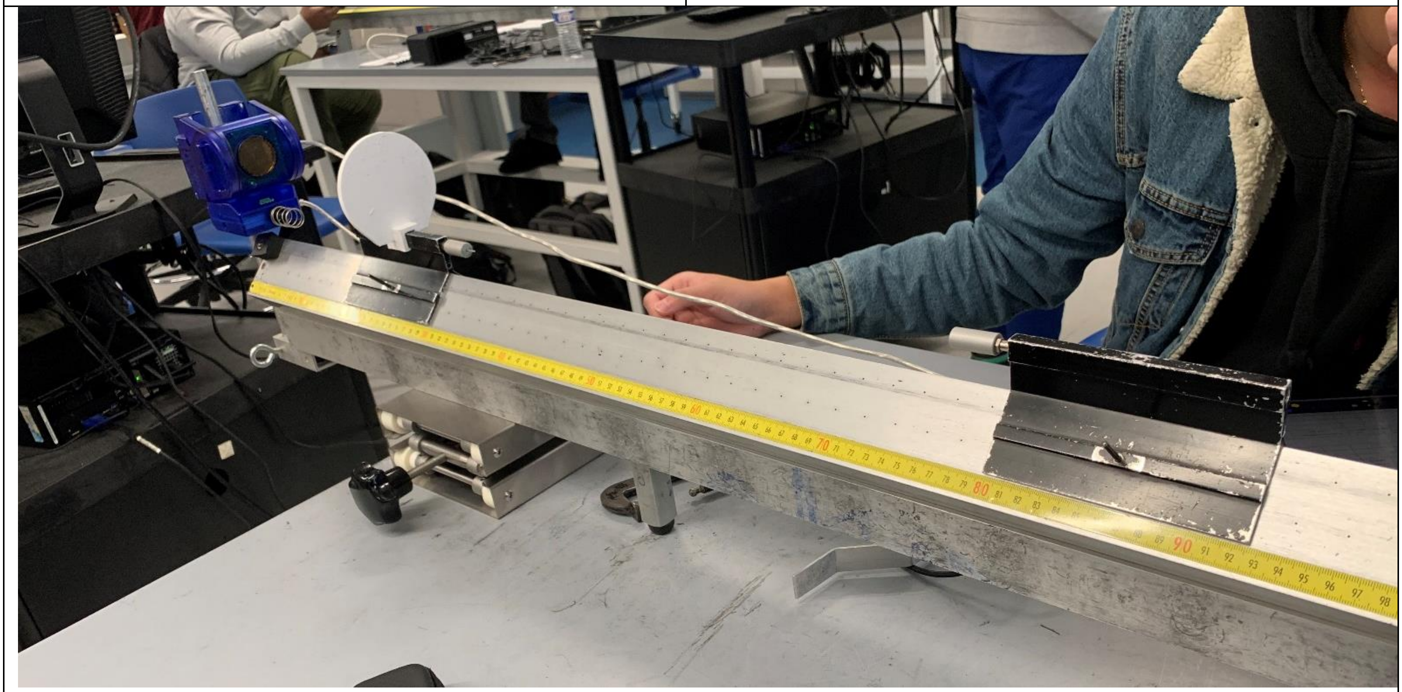
We used the same procedure as the manual instructed.

Mass of M1 (0.20958 kg)

Mass of M2 – no extra weight (.18961 kg)



Mass of M2 – 2 extra weights (.28915 kg)	Mass of M2 – 4 extra weights (.38921 kg)



Experimental Setup

Variables

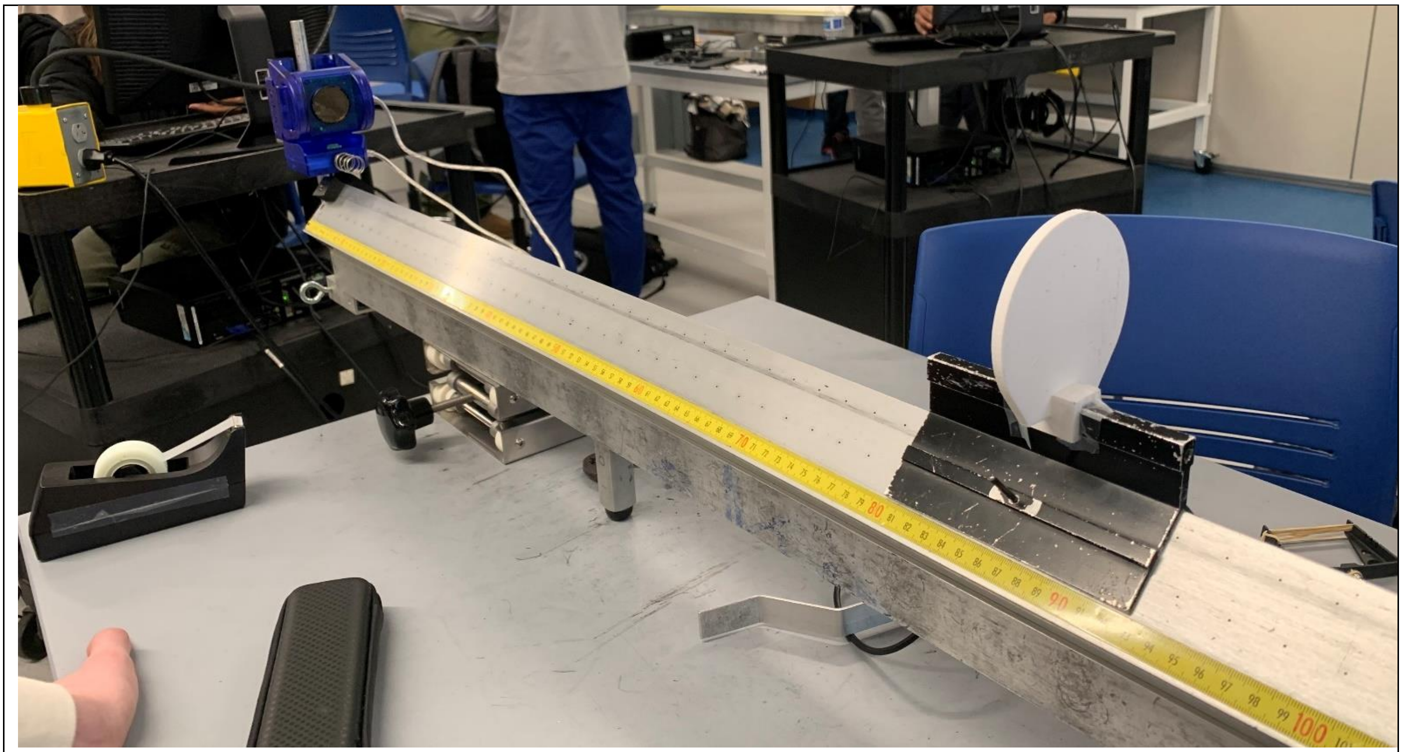
- Momentum of Glider 1 (P1)
- Momentum of Glider 2 (P2)
- Total Momentum Before Collision (P_{tot})
- Momentum of Glider 1 After Collision (P1')
- Momentum of Glider 2 After Collision (P2')
- Total Momentum After Collision (P_{tot}')

Part Three

We used the same procedure as the manual instructed.

 Mass of M – No extra weight (0.19996 kg)	 Mass of M – 2 extra weights (.29973 kg)

Mass of M – 4 extra weights (.39968 kg)



Experimental Setup

Variables

- Kinetic Energy of Glider 1 Before Collision (KE1)
- Kinetic Energy of Glider 2 Before Collision (KE2)
- Total Kinetic Energy Before Collision (KE_{tot})
- Kinetic Energy of Glider 1 After Collision (KE1’)
- Kinetic Energy of Glider 2 After Collision (KE2’)
- Total Kinetic Energy After Collision (KE_{tot}’)
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3 RESULTS

Part One

	Run #1	Run #1	Run #1	Run #1
	Time at photogate 1, Ch A:1 (s)	Time at photogate 2, Ch A:2 (s)	Velocity at photogate 1 (m/s)	Velocity at photogate 2 (m/s)
1	0.1553	0.1580	0.5147	0.5053
2				
3				
4				
5				

	Run #2 Time at photogate 1, Ch A:1 (s)	Run #2 Time at photogate 2, Ch A:2 (s)	Run #2 Velocity at photogate 1 (m/s)	Run #2 Velocity at photogate 2 (m/s)
1	0.0706	0.0994	1.1316	0.8035
2	0.4150	0.2110	0.1926	0.3785
3				
4				

	Run #3 Time at photogate 1, Ch A:1 (s)	Run #3 Time at photogate 2, Ch A:2 (s)	Run #3 Velocity at photogate 1 (m/s)	Run #3 Velocity at photogate 2 (m/s)
1	0.0815	0.1271	0.9814	0.6282
2	0.3199		0.2499	
3				
4				

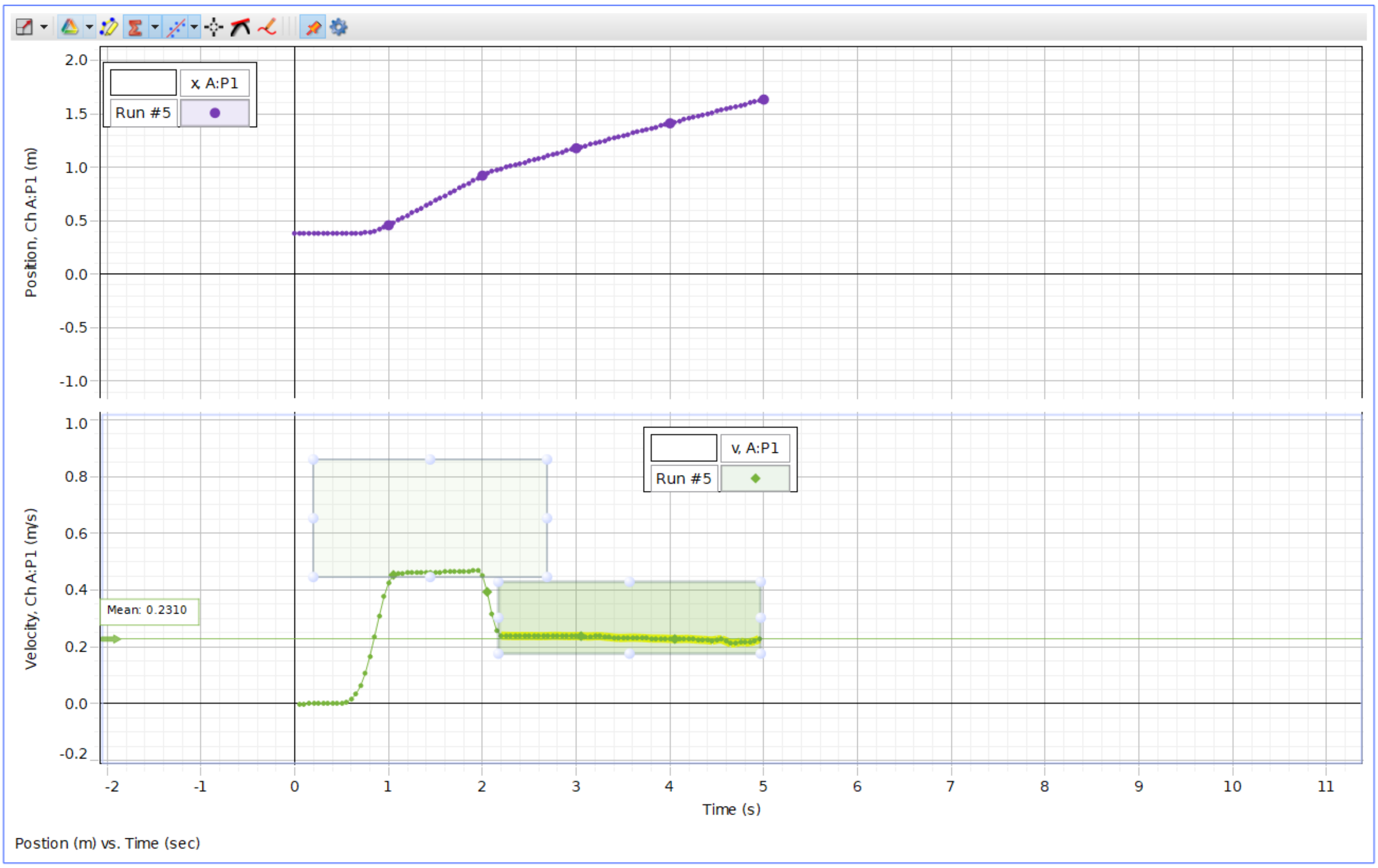
Trial	M1 [kg]	M2 [kg]	V1 [m/s]	V1' [m/2]	V2 [m/s]	V2'
1	0.21156	0.21173	0.5147	0	0	0.5053
2	0.21156	0.31152	1.1316	-0.1926	0	0.8035
3	0.21156	0.41121	0.9814	-0.2499	0	0.6282

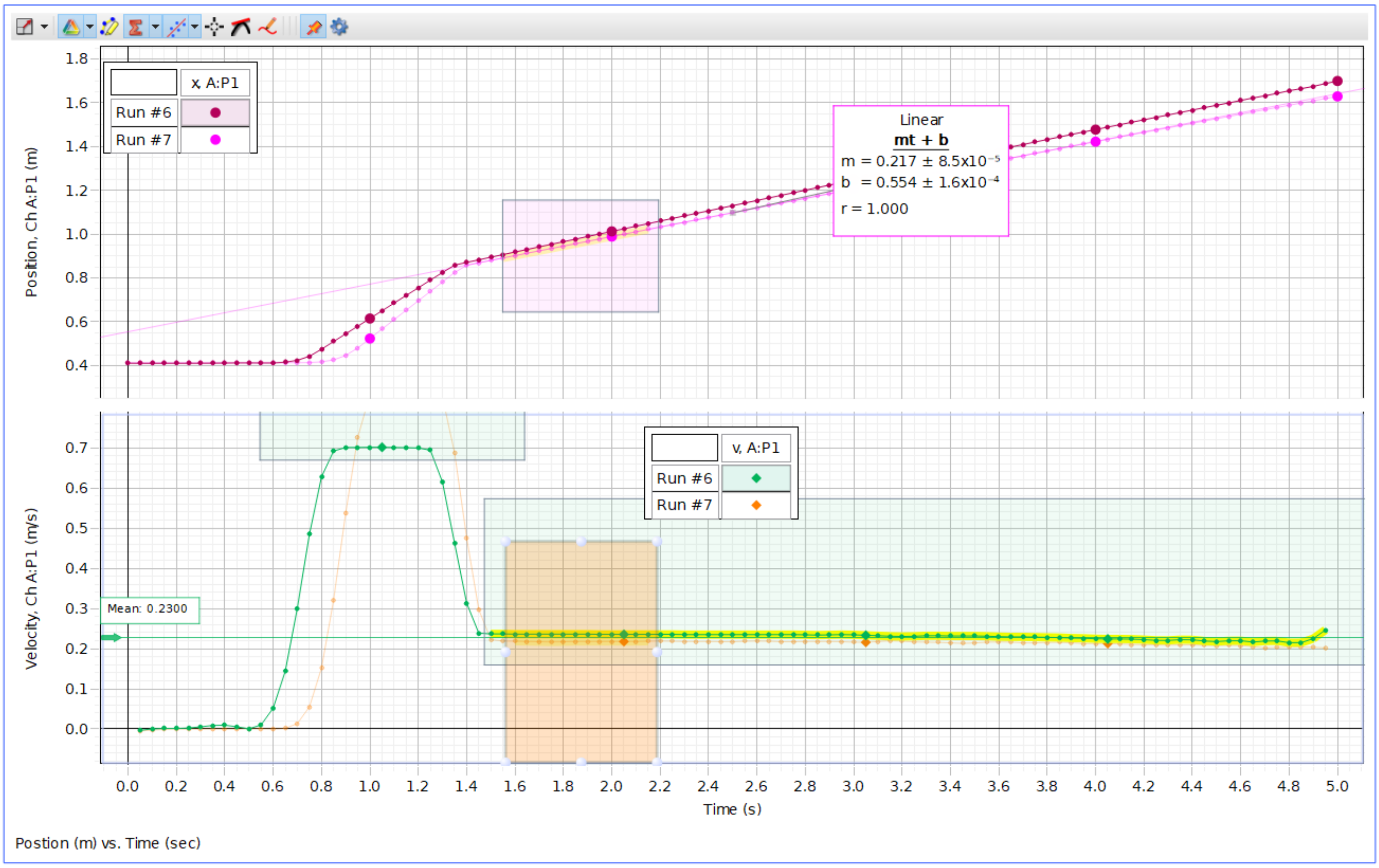
Trial	P1 [kg*m/s]	P2 [kg*m/s]	P1+2 [kg*m/s]	P1' [kg*m/s]	P2' [kg*m/s]	P1'+2' [kg*m/s]	% Difference
1	0.1089	0	0.1089	0	0.1070	0.1070	1.7%
2	0.1354	0	0.1354	-0.0407	0.2503	0.2096	12%
3	0.1019	0	0.1019	-0.0529	0.02583	0.2054	1.05%

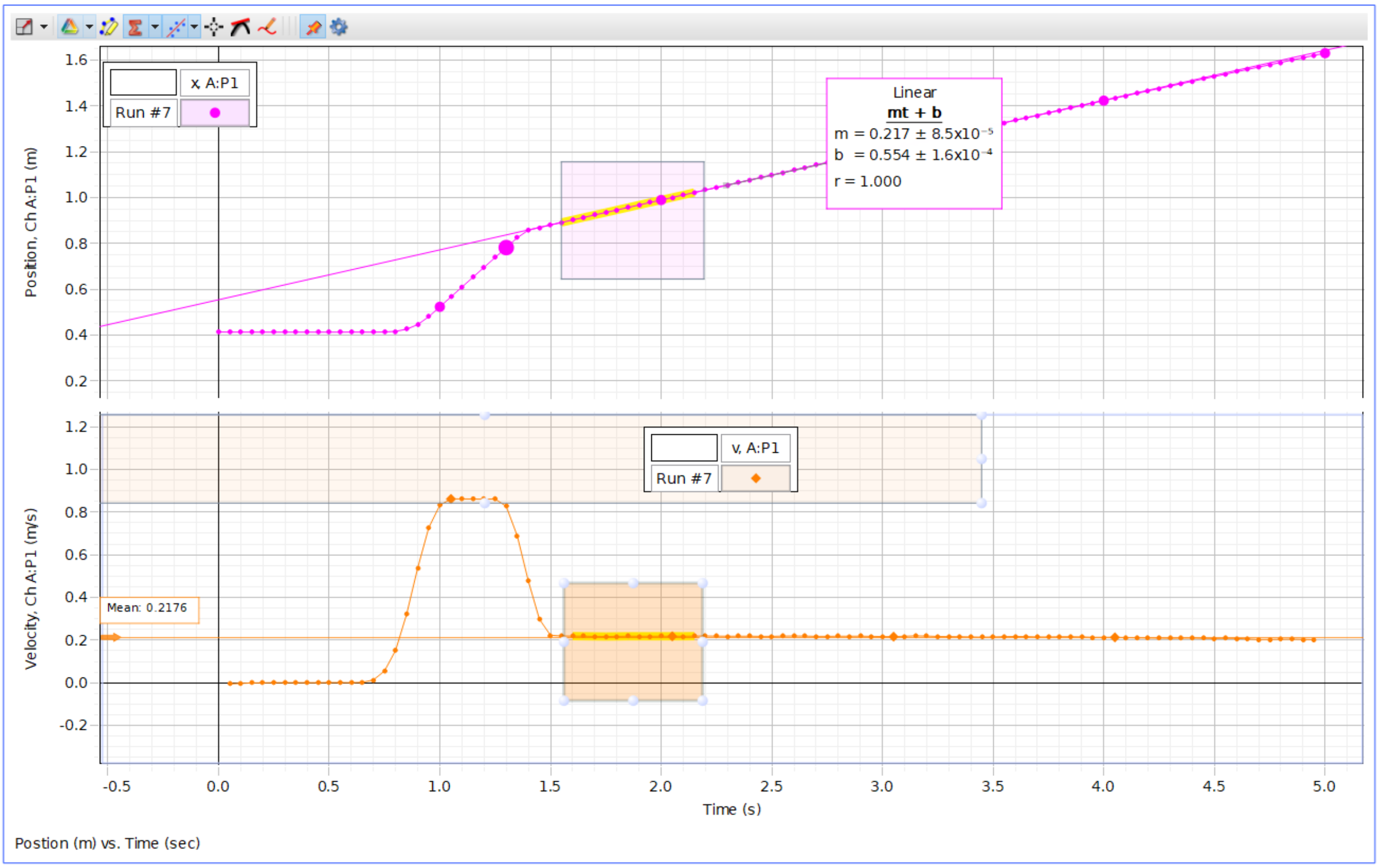
Trial	KE1 [J]	KE2 [J]	KE1+2 [J]	KE1' [J]	KE2' [J]	KE1'+2' [J]	% Difference
1	0.02802	0	0.02802	0	0.02703	0.02703	3.53%
2	0.1354	0	0.1354	0.003923	0.1005	1.044	22.9%
3	0.1019	0	0.1019	0.00667	0.08114	0.0877	13.9%

No hand-written calculations were used for this part.

Part Two


x, A:P1
Run #5
Position, Ch A:P1 (m)
v, A:P1
Run #5
Mean: 0.2310
Velocity, Ch A:P1 (m/s)
Time (s)
Postion (m) vs. Time (sec)


x, A:P1
Run #6
Run #7
Linear
mt + b
m = 0.217 ± 8.5x10⁻⁵
b = 0.554 ± 1.6x10⁻⁴
r = 1.000
Position, Ch A:P1 (m)
v, A:P1
Run #6
Run #7
Mean: 0.2300
Velocity, Ch A:P1 (m/s)
Time (s)
Postion (m) vs. Time (sec)



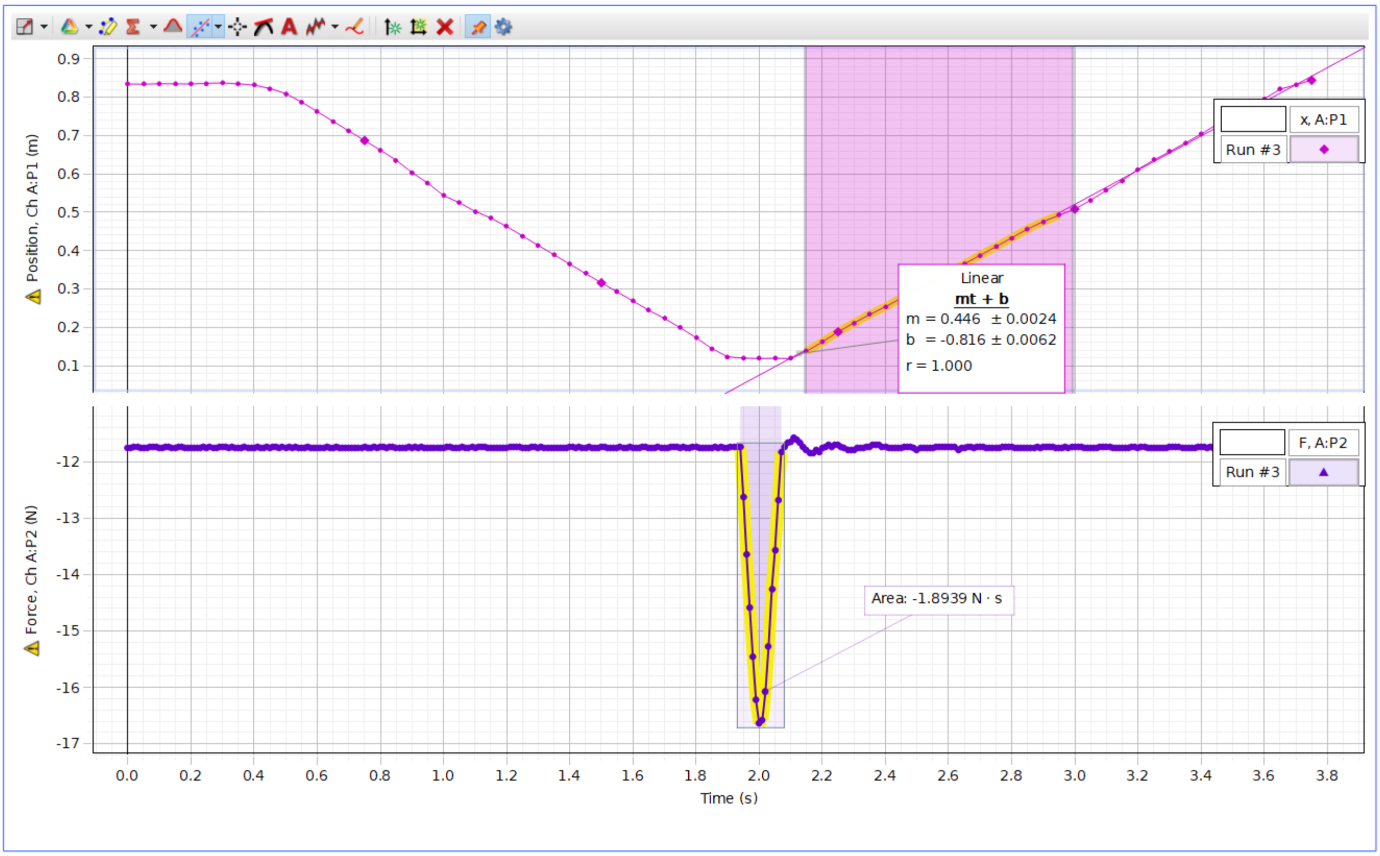
The table was split into two for spacing.

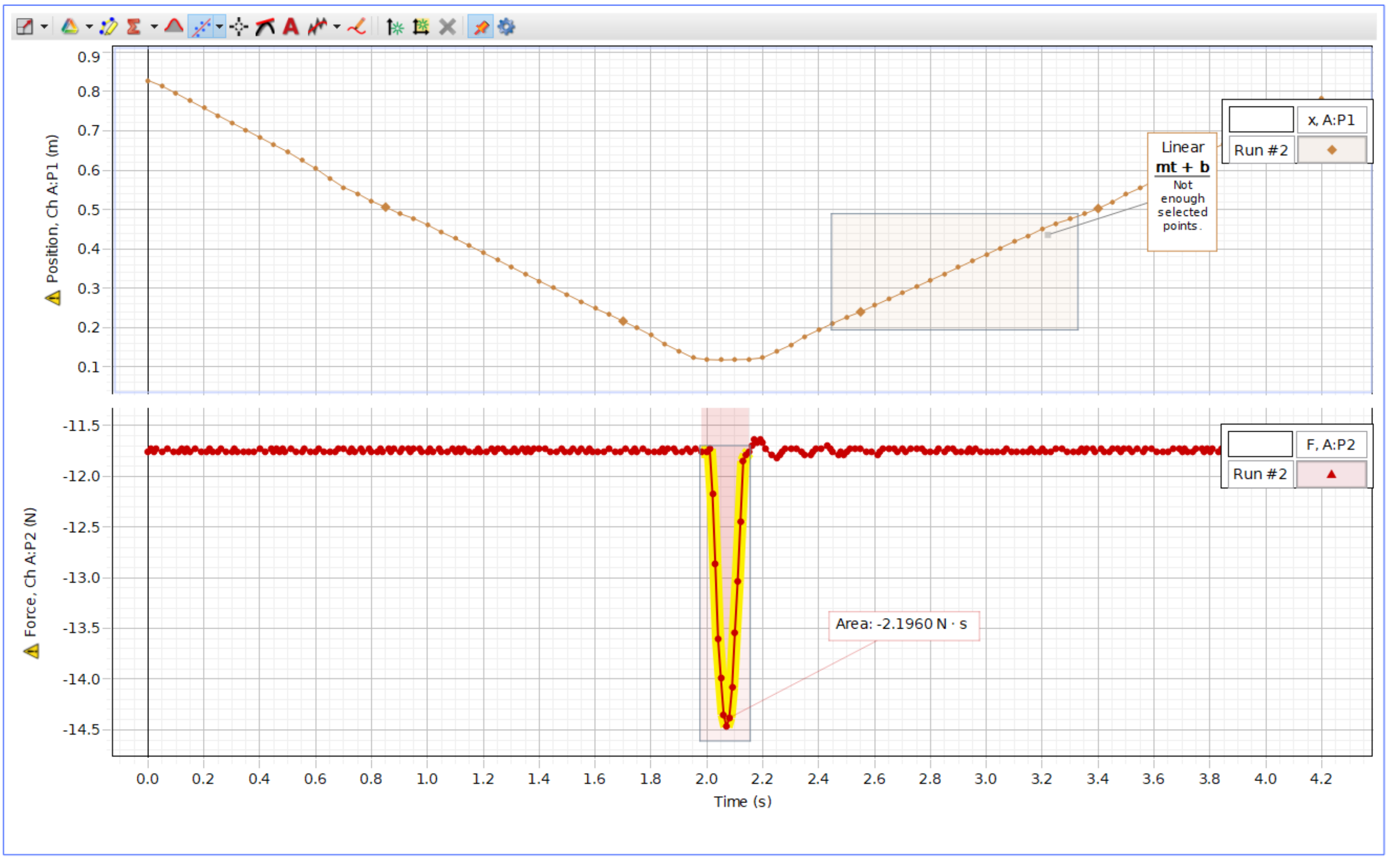
Trial	M1 [kg]	M2 [kg]	$V_{initial}$ [m/s]	V_{final} [m/s]
1	0.20958	0.18961	0.4627	0.2310
2	0.20958	0.28915	0.6999	0.2300
3	0.20958	0.38921	0.8609	0.2176

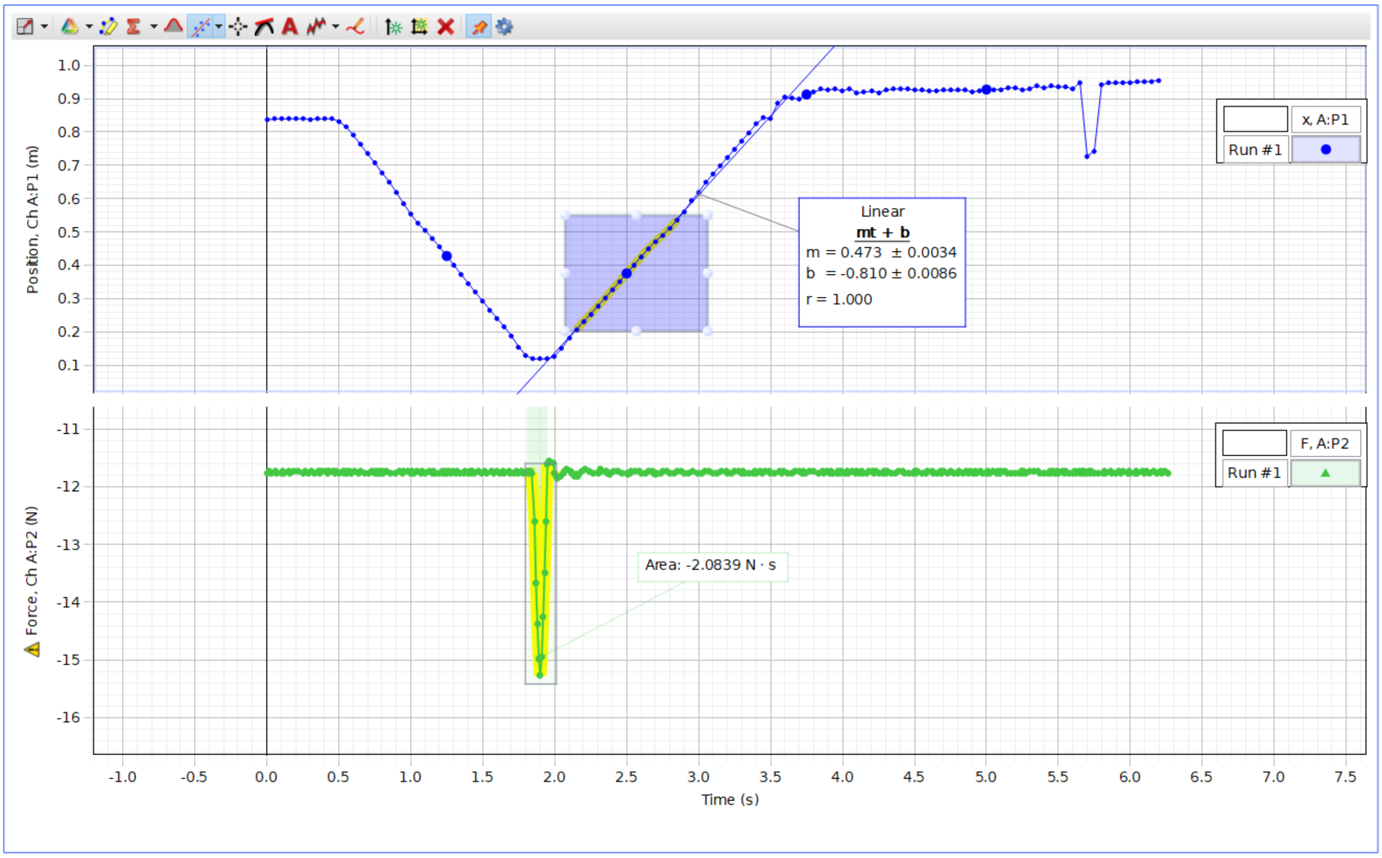
Trial	P_{before} [kg*m/s]	P_{after} [kg*m/s]	KE_{before} [J]	KE_{after} [J]
1	0.09697	0.09221	0.02243	0.01065
2	0.1467	0.1147	0.5133	0.01319
3	0.1804	0.1303	0.7766	0.01418

No hand-written calculations were used for this part.

Part Three


Position, Ch A:P1 (m)
Force, Ch A:P2 (N)
Time (s)
x, A:P1
Run #3
F, A:P2
Run #3
Linear
mt + b
m = 0.446 ± 0.0024
b = -0.816 ± 0.0062
r = 1.000
Area: -1.8939 N · s


Position, Ch A:P1 (m)
Force, Ch A:P2 (N)
Time (s)
x, A:P1
Run #2
F, A:P2
Run #2
Linear
mt + b
Not enough selected points.
Area: -2.1960 N · s

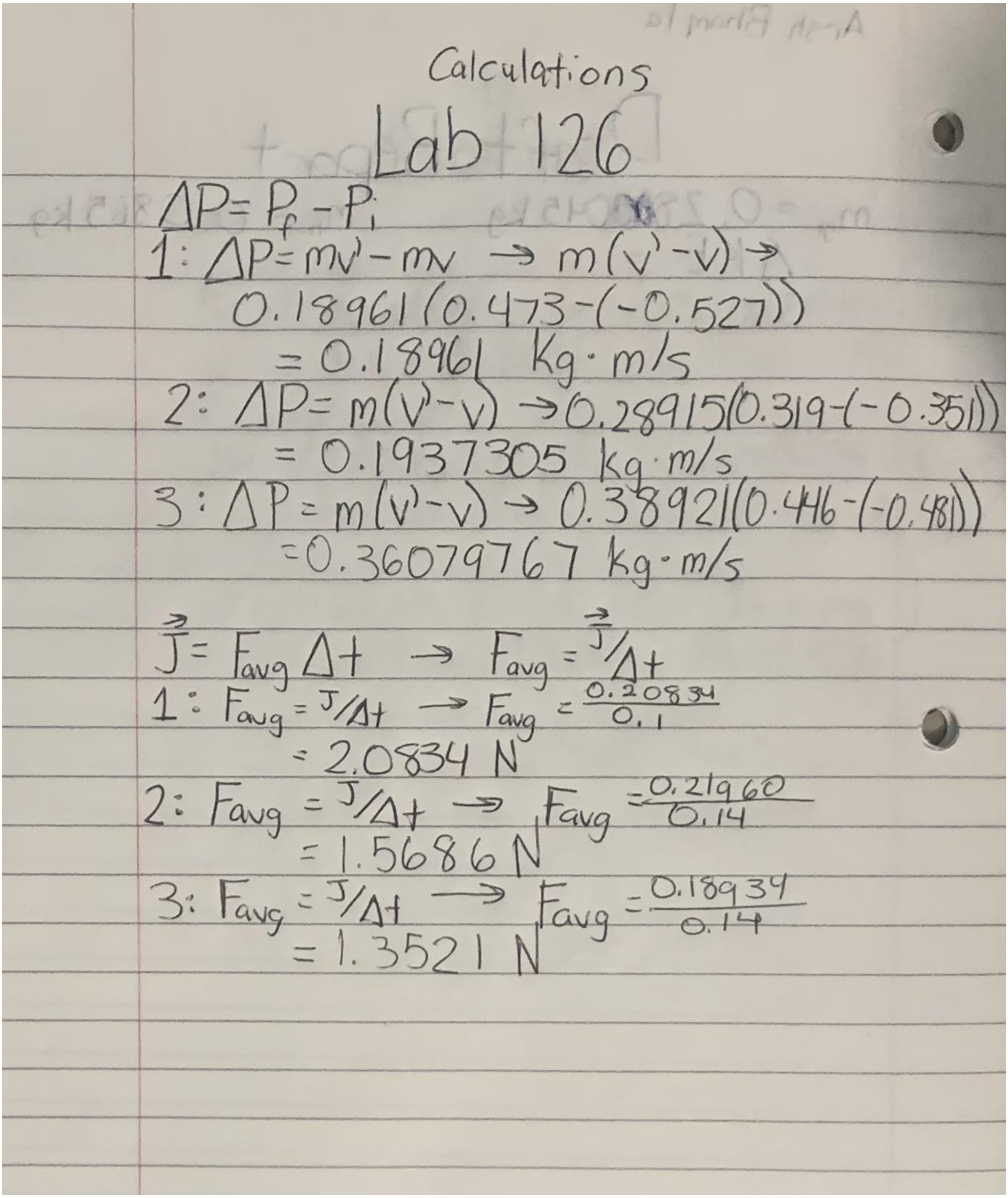


The table was split into two for spacing.

Trial	M [kg]	V [m/s]	V’ [m/s]	J [kg*m/s]
1	0.18961	-0.527	0.473	0.20834
2	0.28915	-0.351	0.319	0.21960
3	0.38921	-0.481	0.446	0.18934

Trial	ΔP [kg*m/s]	% Difference	Δt [s]	F_{avg} [N]
1	0.18961	8.99%	0.10	2.0834
2	0.1937	12.4%	0.14	1.5686
3	0.3608	8.23%	0.14	1.2321

Calculations for Part Three


Calculations

Lab 126

$\Delta P = P_f - P_i$

1: $\Delta P = mv' - mv \rightarrow m(v' - v) \rightarrow$
$0.18961(0.473 - (-0.527))$
$= 0.18961 \ Kg \cdot m/s$

2: $\Delta P = m(v' - v) \rightarrow 0.28915(0.319 - (-0.351))$
$= 0.1937305 \ kg \cdot m/s$

3: $\Delta P = m(v' - v) \rightarrow 0.38921(0.446 - (-0.481))$
$= 0.36079767 \ kg \cdot m/s$

$\vec{J} = F_{avg} \Delta t \rightarrow F_{avg} = \vec{J}/\Delta t$

1: $F_{avg} = J/\Delta t \rightarrow F_{avg} = \frac{0.20834}{0.1}$
$= 2.0834 \ N$

2: $F_{avg} = J/\Delta t \rightarrow F_{avg} = \frac{0.21960}{0.14}$
$= 1.5686 \ N$

3: $F_{avg} = J/\Delta t \rightarrow F_{avg} = \frac{0.18934}{0.14}$
$= 1.3521 \ N$

4 ANALYSIS and DISCUSSION

As explained in the introduction, we had to apply our understanding of momentum and impulse, and all of the factors that make up these values. The experiment had us use the computer for many of the values, and we had to find others using experimentation (like with the masses), and then using our learned knowledge of physics applying it to solve for the objectives. There is error margins to also go over. In part one, the error percentages for trials 1 and 3 were relatively low, while part two was a much higher value. I believe this is the case because of the force that was exerted was much greater than for the other two, and possibly my groupmate's hand or some other factor may have been counted. Part two did not have a calculated margin of error. In part three, we saw the difference between the impulse and change in momentum was at a moderate and relatively stable amount. This could be for a variety of reasons, but most importantly being the loss of energy in the collision, something the theoretical did not account for.

There are two discussion questions that we must review for this week's lab. The first question asks us to calculate the percent difference between both the momentum and the kinetic energy and explain why this value is the way it is. The table in the results section already shows these values, being 1.7%, 12%, and 1.05% for momentum, and 3.53%, 22.9%, and 13.9% for kinetic energy. It has already explained why the values drastically change between the trials, but this question wants us to discuss the trend between kinetic energy and momentum. Momentum's values are much lower, around ½ of the error percentage of kinetic energy, likely because the error comes from the velocity. Because kinetic energy is calculated using $KE = \frac{1}{2} mv^2$, the error becomes a much larger factor in the output. Question two asks us to show that fractional energy loss is equal to M2/(M1 + M2). We can take the values from our equation to get (0.18961) / (0.20958 + 0.18961) = 0.474986. This is the ratio of what is lost in part two, trial one. Multiplying this value by the before collision energy (0.02243) gives us a value of 0.010653955J. The actual value is 0.01065, which is a negligible difference.

5 CONCLUSIONS

In summary, we learned what momentum and impulse were as new concepts to be implemented in collisions. Furthermore, we learned how to apply our previously understood lessons on forces, velocity, and energy to derive these equations. I found this lab to be a great amount of experience which I will be applying in my main physics class. I have more questions, especially about the impact of the rubber bands and pin in parts one and two. They likely have some spring force and friction (respectively) which can also be calculated for. I would like to have new experiments where we change those values in the future, and also find out new variables to put everything we learned together. Overall, I found this lab very insightful.