

# Motion on a linear air track

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## Identification page

**Instructions:** Print this page and the following ones before your lab session to prepare your lab report. Staple them together with your graphs at the end. If you forgot to print it before your lab, you can reproduce it by hand but you have to follow the exact format (same number of pages, same items on each page, same space to answer question).

Complete all the identification fields below or 10% of the lab value will be deducted from your final mark for this lab.

For in-lab reports, hand in your report to your demonstrator at the end of the sessions or you will receive a zero for this lab.

For take-home reports, drop your report in the right box or 10% of the lab value will be deducted from your mark. Refer to the *General information* document for the details of the late report policy.

Experiment title: Motion on a linear air track

Name: \_\_\_\_\_

Student number: \_\_\_\_\_

Lab group number: \_\_\_\_\_

Course code: PHY 1331 - B

Demonstrator: \_\_\_\_\_

Date of the lab session: 2017-10-16

Partner's name: \_\_\_\_\_

## Data sheet

**Instructions:** Use a pen to complete this section before the end of the lab session. Ask your TA to initialize your data before you leave the laboratory.

### Preliminary manipulations (simple motion on an incline)

[6] Prepare Graphs 1 and 2. Print them to a pdf file. Send the file to yourself by email or save it on a USB key. Print the graphs and attach them at the end of your report.

[1] What are the values of the  $A$  and  $B$  parameters in the quadratic equation in Graph 1? Provide the units.

$$A = (-0.0510192 \text{ m/s}^2 \pm 0.0000461186 \text{ m/s}^2) \quad B = (0.633057 \text{ m/s} \pm 0.000608354 \text{ m/s})$$

[4] What are the values of  $m$  (slope) and  $b$  (Y-intercept) in Graph 2? Provide the units.

$$m = (-0.101554 \text{ m/s}^2 \pm 0.000166068 \text{ m/s}^2) \quad b = (0.632019 \text{ m/s} \pm 0.00112105 \text{ m/s})$$

### Part 1 - Determining $g$ on an incline

[1] Record the thicknesses of the 3 discs using the vernier caliper. Provide the units.

$$\text{Thickness of disc 1} = (20.1 \text{ mm} \pm 0.05 \text{ mm})$$

$$\text{Thickness of disc 2} = (20.0 \text{ mm} \pm 0.05 \text{ mm})$$

$$\text{Thickness of disc 3} = (10.0 \text{ mm} \pm 0.05 \text{ mm})$$

[5] Fill the following table (you do not have to provide uncertainties for this table):

Table 1 - Acceleration of a glider sliding down various inclines

Track elevation	Measured height, $h$ (m)	Distance between the legs of the track, $d$ (m)	$\sin \theta$	Acceleration			Average acceleration ( $\text{m/s}^2$ )
				Trial 1 ( $\text{m/s}^2$ )	Trial 2 ( $\text{m/s}^2$ )	Trial 3 ( $\text{m/s}^2$ )	
$\approx 1$ cm	0.0100	1.000	<del>0.00177</del> 0.0100	-0.0436100	-0.0466655	-0.0455092	-0.0452616
$\approx 2$ cm	0.0200	1.000	0.0200	-0.191616	-0.192369	-0.192372	-0.192119
$\approx 3$ cm	0.0300	1.000	0.0300	-0.226986	-0.227312	-0.226975	-0.227092
$\approx 4$ cm	0.0401	1.000	0.0401	-0.382121	-0.382905	-382597	-0.383665
$\approx 5$ cm	0.0501	1.000	0.0501	-0.478279	-0.476966	-0.477478	-0.477741

[4] Prepare Graph 3. Send the file to yourself by email or save it on a USB key. Print the graph and attach it at the end of your report.

**Part 2 - Investigating Newton's second law**

[1] Measure the mass of the glider with string attachment:

$$M = (191.3 \text{ g} \pm 0.1 \text{ g})$$

[5] Fill the following table (you do not have to provide uncertainties for this table):

**Table 2 - Acceleration of a glider horizontally pulled by various forces**

Hanging mass description	Hanging mass, $m$ (g)	$m' = \frac{m}{M + m}$	Acceleration			Average acceleration ( $\text{m/s}^2$ )
			Trial 1 ( $\text{m/s}^2$ )	Trial 2 ( $\text{m/s}^2$ )	Trial 3 ( $\text{m/s}^2$ )	
Empty hook	<del>4.6</del> 4.6	0.023	0.219620	0.219036	0.219337	0.218191
Hook + $\approx$ 5 g	<del>9.84</del> 9.84	0.044	0.461229	0.462641	0.463462	0.462444
Hook + $\approx$ 10 g	<del>15.08</del> 15.08	0.073	0.646105	0.643272	0.643587	0.644321
Hook + $\approx$ 15 g	<del>20.32</del> 20.32	0.096	0.911735	0.910928	0.910719	0.911341
Hook + $\approx$ 20 g	<del>25.56</del> 25.56	0.12	1.11646	1.11943	1.11937	1.11842
Hook + $\approx$ 25 g	<del>30.8</del> 30.8	0.14	1.31897	1.31453	1.31463	1.31604

[4] Prepare Graph 4. Send the file to yourself by email or save it on a USB key. Print the graph and attach it at the end of your report.

## Questions

**Instructions:** You can finish this section at home. We encourage you to start answering these questions while you are still in the lab and the TA is available to help you.

### Preliminary manipulations (simple motion on an incline)

- [2] On Graph 2, identify the moment(s) when the glider was:
- being pushed by your hand;
  - moving freely up the ramp;
  - farthest from its initial position;
  - rolling freely down the ramp.

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2
- [2] The slope of a graph represents the rate of change of the variables that were plotted. What can you say about the rate of change of the velocity as a function of time while the cart was rolling freely? In your discussion, you will give a name to this quantity. What is the significance of the algebraic sign of the slope? → *acc. is constant*

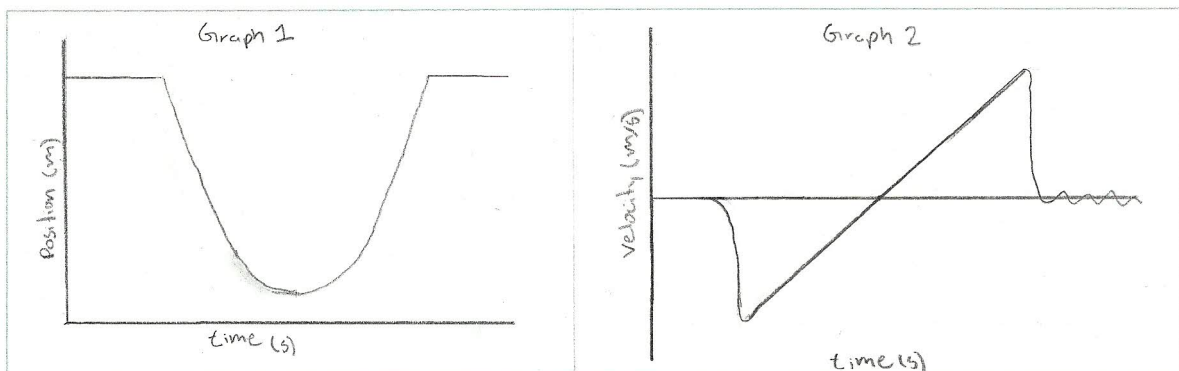
*The rate of change of the velocity as a function of time is equal to the glider's acceleration during its free rolling motion. The negative slope indicates that the glider is ~~slowing down~~ in the direction heading away from the motion detector throughout this same motion. *decelerating**

- [1] What is the relationship between  $A$  and  $m$ ? Between  $B$  and  $b$ ?

*$m$  represents the glider's acceleration during free roll and  $A$  represents half of that:  $A = \frac{1}{2} m$*

*$B$  and  $b$  both represent a fictitious initial velocity for the glider's entire motion:  $B = b$ .*

- [2] Qualitatively sketch the position vs. time and velocity vs. time graphs you would get if the motion detector was placed at the other end of the track.



### Part 1 - Determining $g$ on an incline

- [1] Use the linear fit from Graph 3 to determine your experimental value for  $g$  with uncertainty.

$$g = (-9.33642 \text{ m/s}^2 \pm 0.295342 \text{ m/s}^2)$$

- [1] Compare your value of  $g$  with the accepted value of  $9.81 \text{ m/s}^2$ . Calculate the percentage difference

$$\% \text{diff} = \left| \frac{g_{\text{accepted}} - g_{\text{experimental}}}{g_{\text{accepted}}} \right| \times 100,$$

and discuss.

$\% \text{diff} = 4.83\%$ .  $|g_{\text{experimental}}|$  is less than  $g_{\text{accepted}}$ . This may be caused by friction being assumed to be negligible. Since friction is a resistive force, it would slow the glider down, decreasing  $|g_{\text{experimental}}|$ .

- [1] In the linear fit of Graph 3, what is the physical meaning of the Y-intercept value?

The Y-intercept represents the glider's acceleration when the linear air track is perfectly horizontal which is  $0 \text{ m/s}^2$ .

## Part 2 - Investigating Newton's second law

- [1] Use the linear fit from Graph 4 to determine your experimental value for  $g$  with uncertainty.

$$g = (9.33387 \text{ m/s}^2 \pm 0.104748 \text{ m/s}^2)$$

- [1] Compare your value of  $g$  with the accepted value of  $9.81 \text{ m/s}^2$ . Calculate the percentage difference

$$\% \text{diff} = \left| \frac{g_{\text{accepted}} - g_{\text{experimental}}}{g_{\text{accepted}}} \right| \times 100,$$

and discuss.

$\% \text{ diff} = 4.85\%$ .  $g_{\text{experimental}}$  may be less than  $g_{\text{accepted}}$  because the friction between the linear air track and the glider and the friction between the pulley and the string attached to the hanging mass are both assumed to be negligible when they do affect the system.

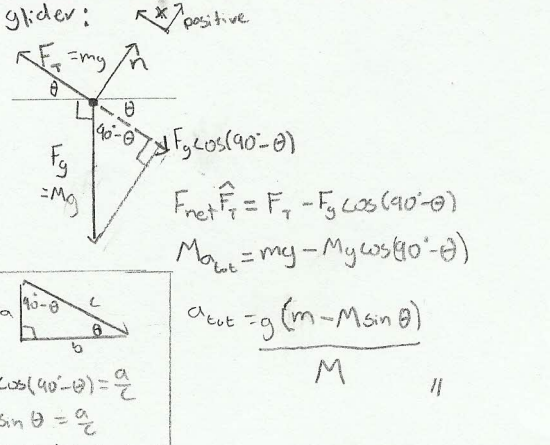
- [1] In the linear fit of Graph 4, what is the physical meaning of the Y-intercept value?

The Y-intercept represents the acceleration of the glider when the hanging mass is removed which is  $0 \text{ m/s}^2$ .

- [1] Do your results agree with Newton's 2<sup>nd</sup> law?

Yes. Increasing the hanging mass, which increases the value of  $m$ , increases the net force acting on the glider. The results show that acceleration increases with heavier hanging masses, agreeing with Newton's 2<sup>nd</sup> law.

- [2] ✓ Suppose that you have a situation with a combination of acceleration due to the inclined plane as well as the force of the weights as in [Figure 1](#) below:
- Derive an equation that predicts the total acceleration of the glider.
  - Derive an equation that will allow the system to be in equilibrium (i.e., glider is stationary) for a height,  $h$ .

<p>glider: <math>\leftarrow x \rightarrow</math> positive</p>  <p> <math>F_T = mg</math>  <math>F_g = Mg</math>  <math>F_{net} = F_T - F_g \cos(90^\circ - \theta)</math>  <math>M a_{tot} = mg - Mg \cos(90^\circ - \theta)</math>  <math>a_{tot} = \frac{g(m - M \sin \theta)}{M}</math> //         </p> <p> <math>\cos(90^\circ - \theta) = \frac{a}{c}</math>  <math>\sin \theta = \frac{a}{c}</math>  <math>\therefore \cos(90^\circ - \theta) = \sin \theta</math> </p>	<p>System is at equilibrium when <math>a_{tot} = 0 \text{ m/s}^2</math>.</p> $0 = \frac{g(m - M \sin \theta)}{M}$ $0 = m - M \frac{h}{d}$ $\frac{Mh}{d} = m$ $h = \frac{md}{M} //$
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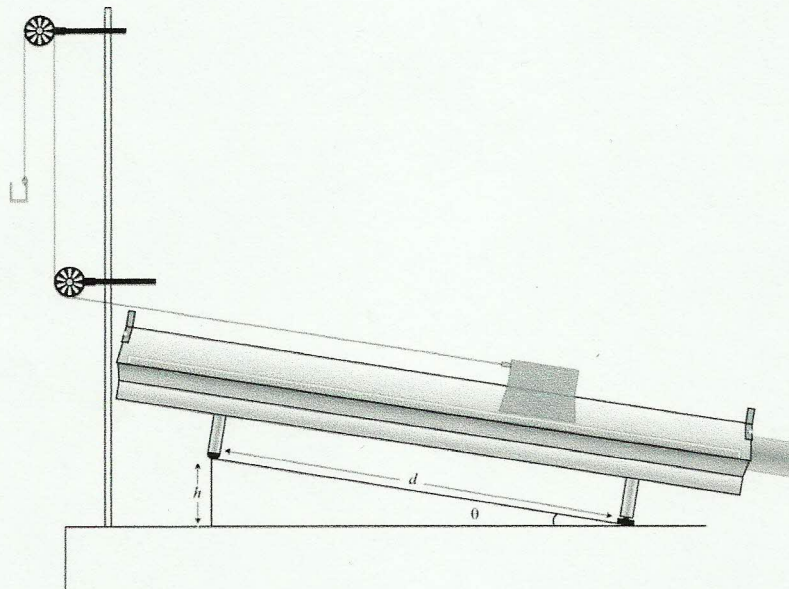
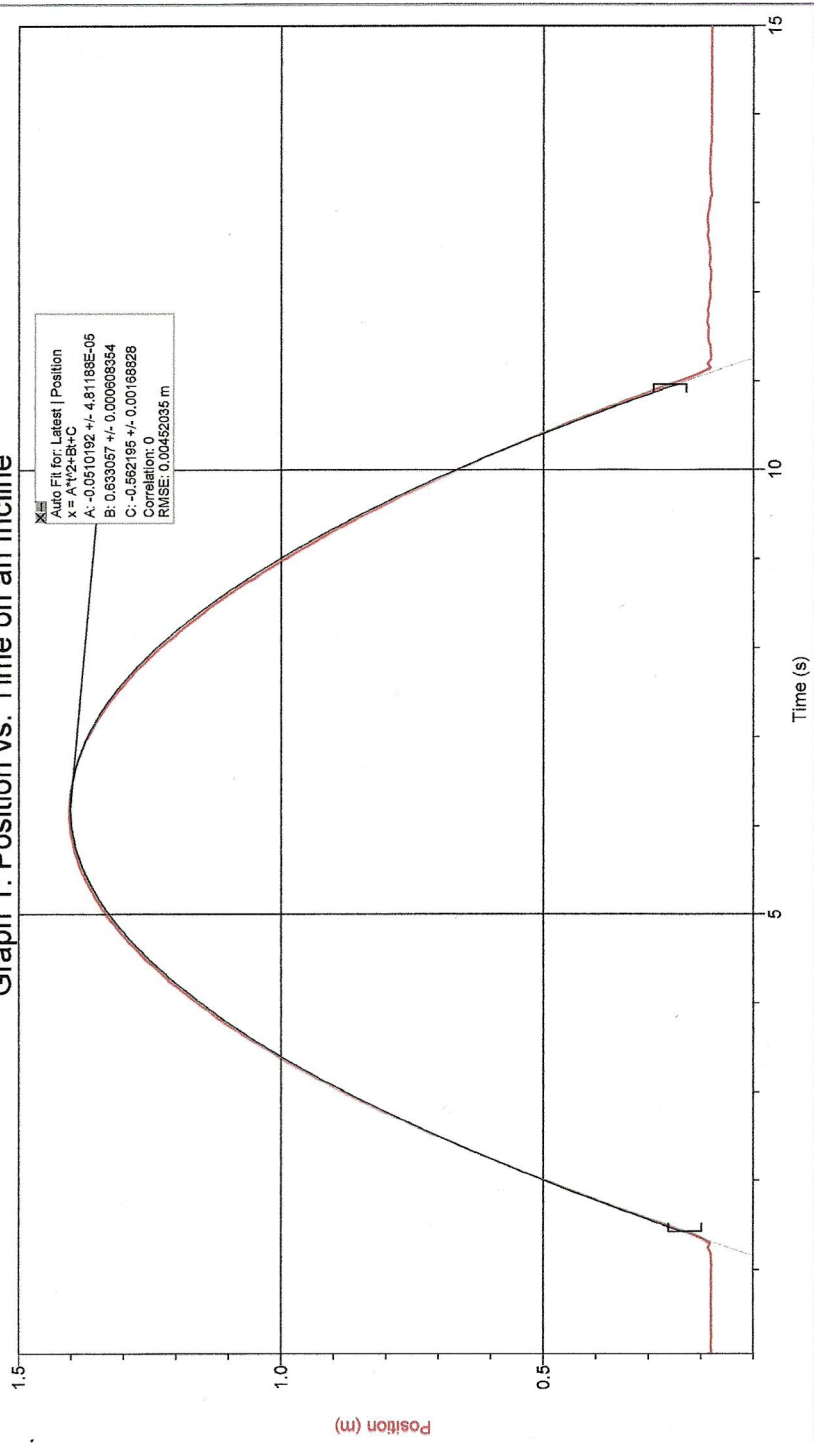


Figure 1 - Glider pulled by a constant force on an inclined air track.

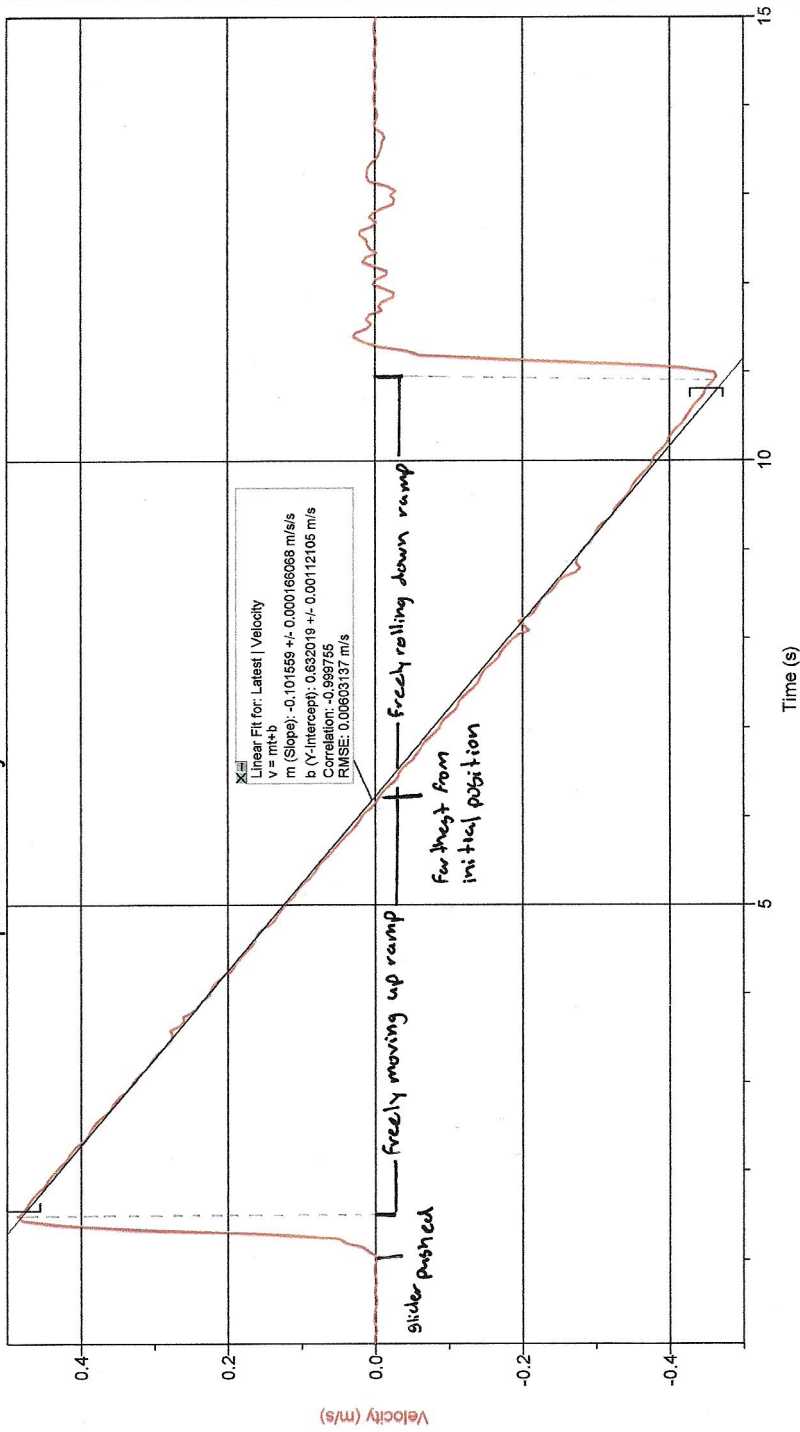
Total : 43 / 44 (for the report)

Graph 1: Position vs. Time on an Incline

Time (s)	Position (m)	Velocity (m/s)
1	0.05	0.180
2	0.10	0.180
3	0.15	0.180
4	0.20	0.180
5	0.25	0.180
6	0.30	0.180
7	0.35	0.180
8	0.40	0.180
9	0.45	0.180
10	0.50	0.180
11	0.55	0.180
12	0.60	0.180
13	0.65	0.180
14	0.70	0.180
15	0.75	0.180
16	0.80	0.180
17	0.85	0.180
18	0.90	0.180
19	0.95	0.180
20	1.00	0.180
21	1.05	0.180
22	1.10	0.180
23	1.15	0.180
24	1.20	0.181
25	1.25	0.186
26	1.30	0.182
27	1.35	0.196
28	1.40	0.217
29	1.45	0.242
30	1.50	0.267
31	1.55	0.291
32	1.60	0.314
33	1.65	0.338
34	1.70	0.362



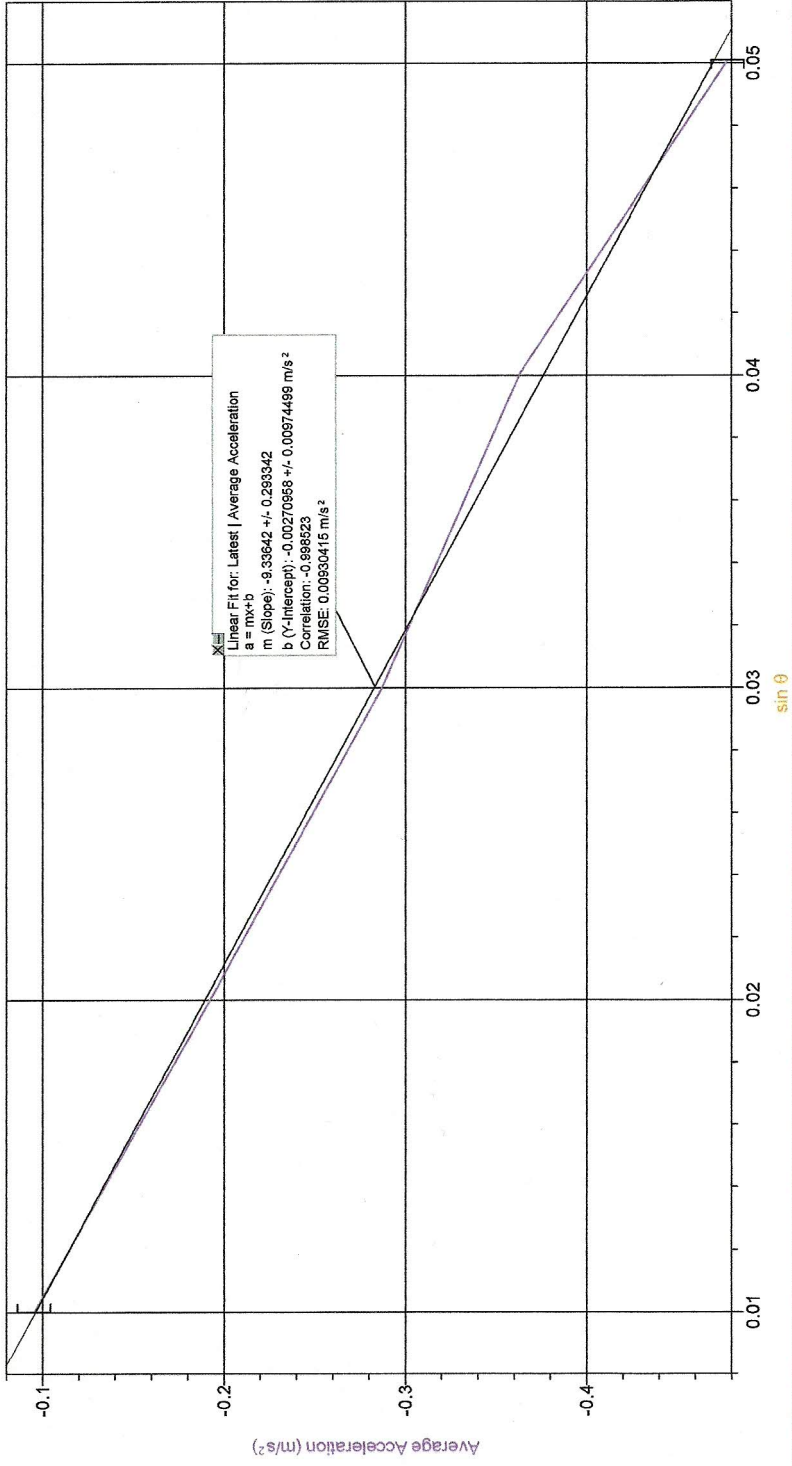
Graph 2: Velocity vs. Time on an Incline



Time (s)	Position (m)	Velocity (m/s)
1	0.05	0.180
2	0.10	0.180
3	0.15	0.180
4	0.20	0.180
5	0.25	0.180
6	0.30	0.180
7	0.35	0.180
8	0.40	0.180
9	0.45	0.180
10	0.50	0.180
11	0.55	0.180
12	0.60	0.180
13	0.65	0.180
14	0.70	0.180
15	0.75	0.180
16	0.80	0.180
17	0.85	0.180
18	0.90	0.180
19	0.95	0.180
20	1.00	0.180
21	1.05	0.180
22	1.10	0.180
23	1.15	0.180
24	1.20	0.181
25	1.25	0.186
26	1.30	0.182
27	1.35	0.196
28	1.40	0.217
29	1.45	0.242
30	1.50	0.267
31	1.55	0.291
32	1.60	0.314
33	1.65	0.338
34	1.70	0.362

	Latest sin θ	a (m/s <sup>2</sup> )
1	0.01	-0.0952616
2	0.02	-0.192119
3	0.03	-0.287092
4	0.0401	-0.363665
5	0.0501	-0.477741
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Graph 3: Acceleration of the Glider as a Function of sin θ of the Incline



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	Latest $m'$ (g)	$a$ ( $m/s^2$ )
1	0.023	0.218191
2	0.049	0.462444
3	0.073	0.684321
4	0.098	0.911134
5	0.12	1.11842
6	0.14	1.31604
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Graph 4: Acceleration of the Glider as a Function of the Dimensionless Hanging Mass,  $m' = m / (m+M)$ .

