Forces

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Purpose: To study the applications of Newton's second law F=ma.

Background:

In this lab we will study Newton's classic equation, F=ma, where F is force, m is mass in kilograms, and a is acceleration in meter's per second squared. So to calculate the force of the fan cart we would multiply mass times acceleration. For the second part when we add the mass the force should be the same, but the acceleration will be less, but the mass is greater so it all should be the same. We can calculate acceleration by taking the displacement and time and solving for a in S= ½at^2 so a= $\frac{2S}{T^2}$.

To calculate the acceleration of the cart on the incline plane we will do $\sin\frac{height}{base}*-9.8$. However we could also work backwards to determine gravity if we know our measurements are accurate and take do $\frac{observed\ acceleration}{\sin\frac{height}{base}}=gravity$ however we would actually need a truly frictionless cart (like a cool magnet cart) in a vacuum for this to work.

Materials:

- A adjustable incline plane.
- Electronic balance or scale.
- A fan cart.
- A laptop with logger pro installed on it.
- A sonic range finder with necessary cables.
- A small weight (about 300 grams).
- A frictionless cart.

Procedure:

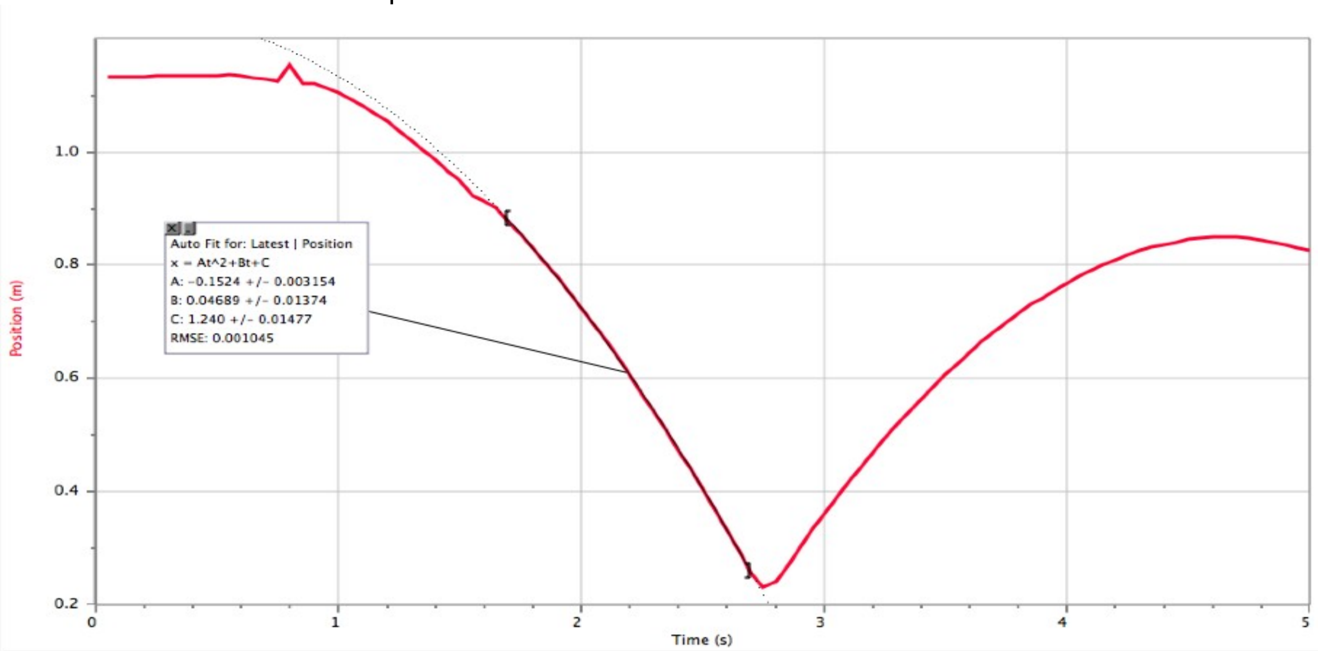
Incline Plane half:

1. Set up the computer, sonic range, and incline plane at about 10°. Aim the range finder at the frictionless cart.
2. Begin recording the distance and let the cart go, after it bounces stop recording.
3. Do a curve fit for the displacement graph, and a linear fit for velocity and acceleration.
4. Increase the angle of the incline plane and repeat steps 1-3.

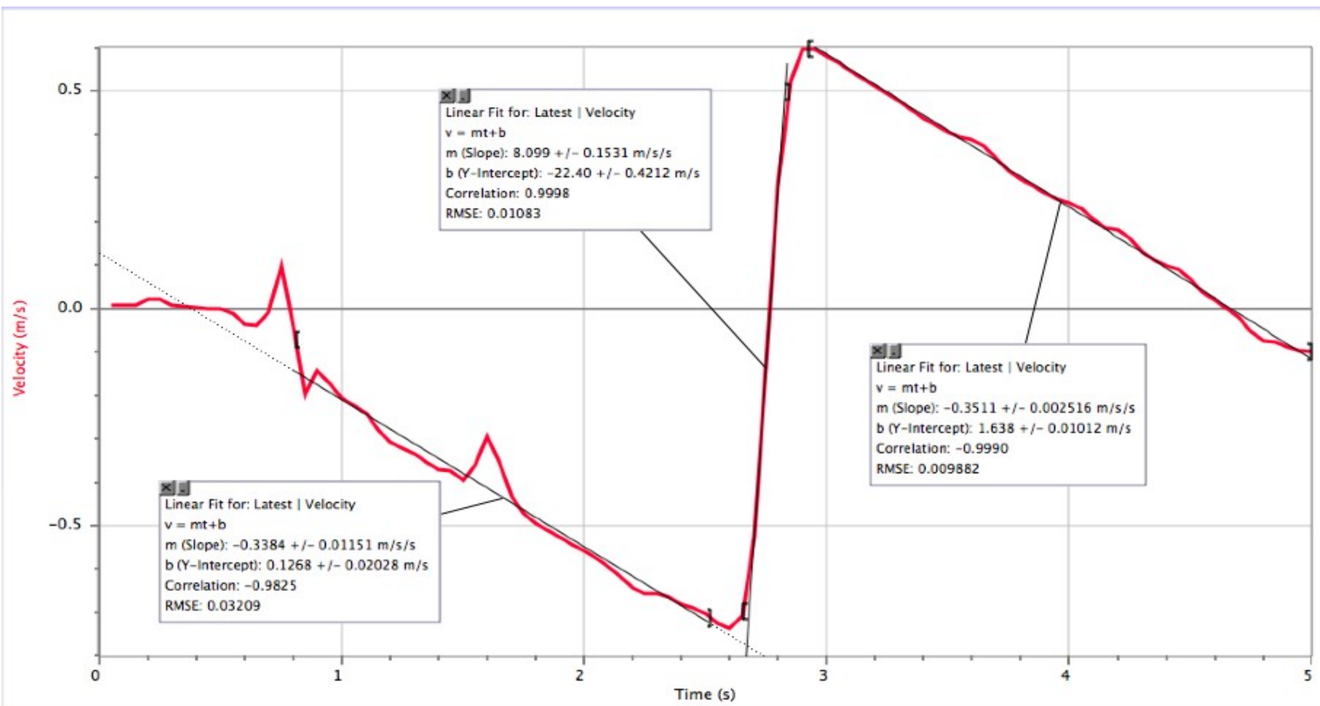
Fan Cart half:

5. Set up the computer, and sonic range. Aim the range finder at the fan cart.
6. Start the range finder and set the fan cart to high and let it go. Repeat this on low as well.
7. Add a small weight to it and repeat step 6.
8. Weigh the weight, and the cart separately.

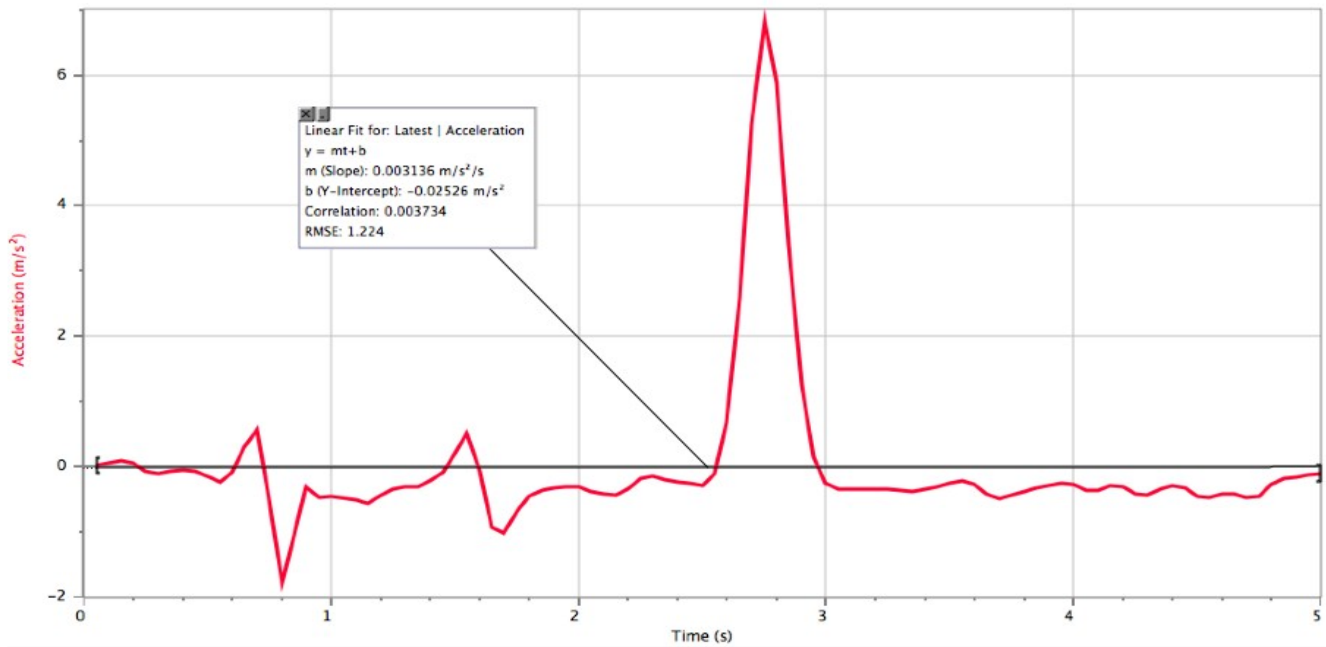
Data:
Incline Plane:
For the first trial the incline plane was set to 1.71°.



Graph 1.1.1 position graph for the cart. Note the A from this is -.152 which is ½ our measured acceleration which is .304.



Graph 1.1.2 velocity graph for the cart. Note the slope of this line is -0.338 which is approximately our acceleration.

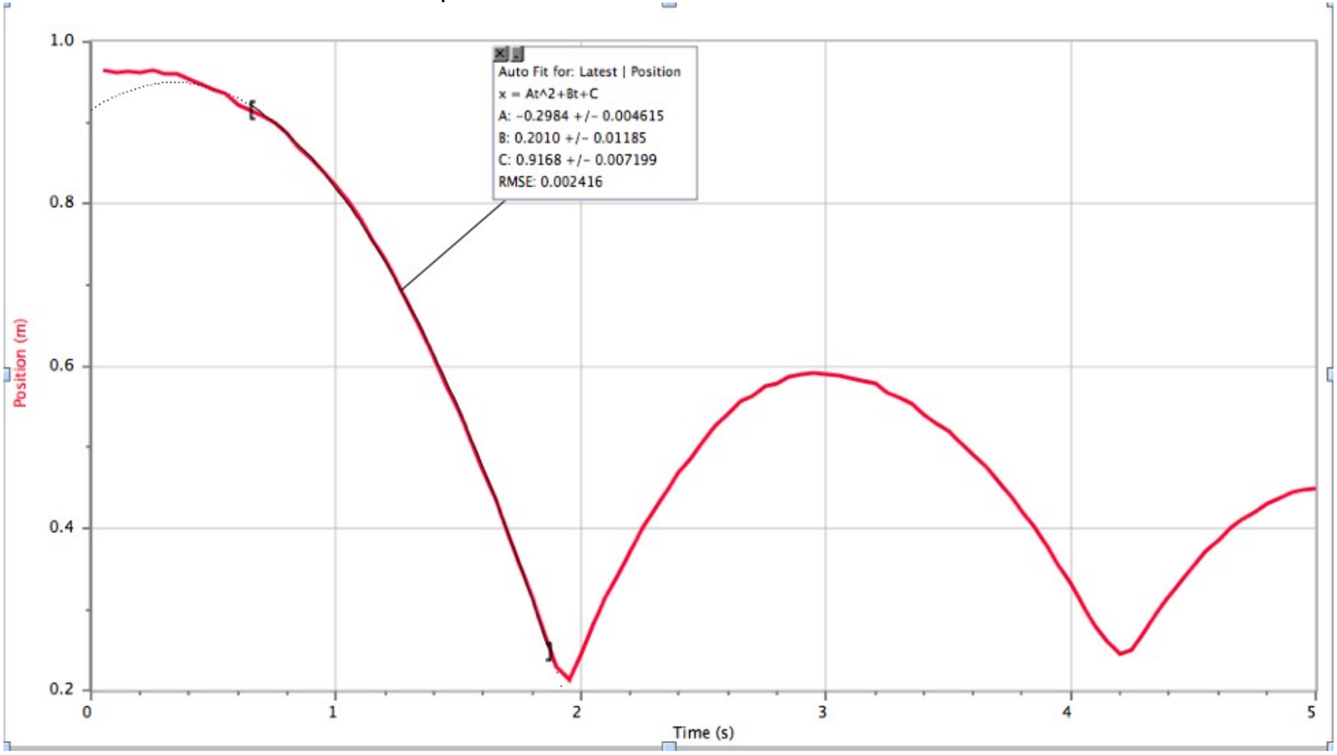


Graph 1.1.3 acceleration graph for the first test. According to this the acceleration was -.025 which is wrong because Beeka did the linear fit for the entire graph so the discontinuity at t= 0.9, 1.7 and 2.8 really messed it up.

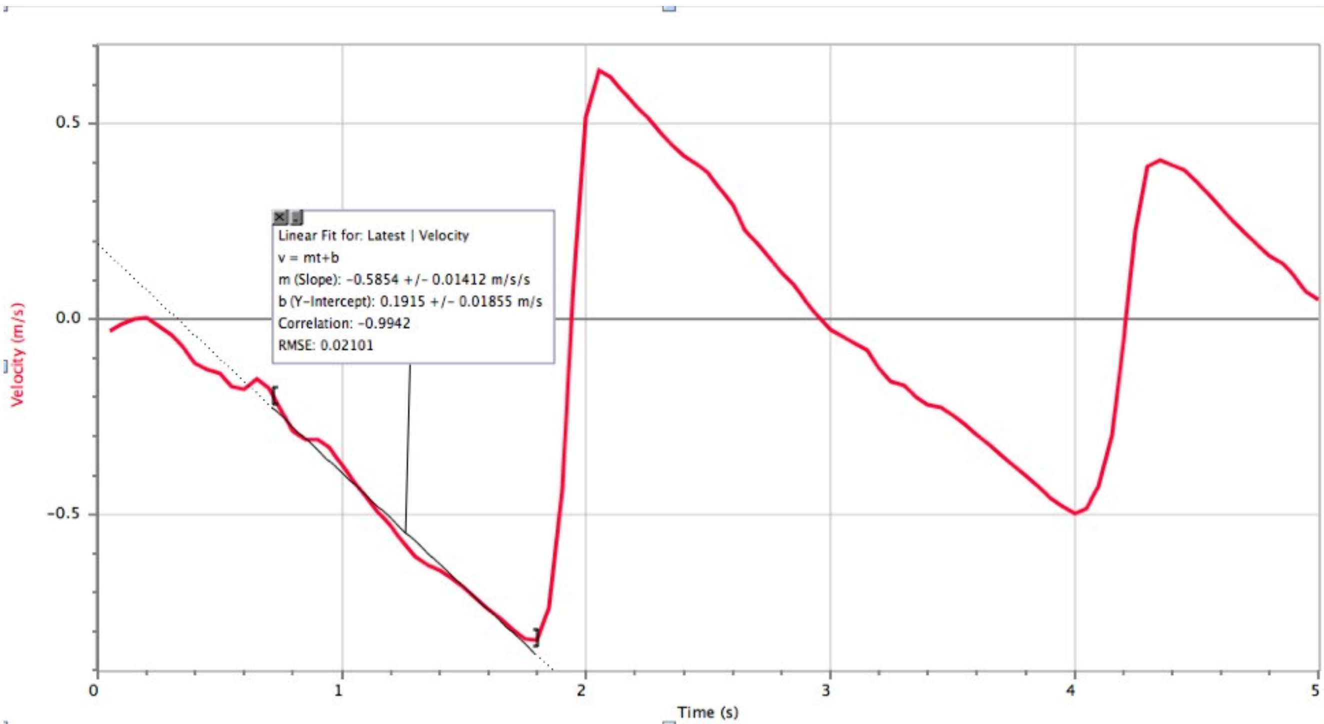
	Latest			
	Time (s)	Position (m)	Velocity (m/s)	acc (m/s²)
1	0.05	1.132	0.007	0.012
2	0.10	1.133	0.006	0.047
3	0.15	1.133	0.008	0.097
4	0.20	1.133	0.021	0.063
5	0.25	1.136	0.020	-0.076
6	0.30	1.135	0.008	-0.118
7	0.35	1.136	0.004	-0.083
8	0.40	1.136	0.001	-0.060
9	0.45	1.136	-0.001	-0.066
10	0.50	1.136	-0.002	-0.141
11	0.55	1.136	-0.012	-0.240
12	0.60	1.135	-0.037	-0.087
13	0.65	1.132	-0.038	0.299
14	0.70	1.129	-0.009	0.569
15	0.75	1.126	0.099	-0.495
16	0.80	1.154	-0.043	-1.778
17	0.85	1.122	-0.197	-1.064
18	0.90	1.121	-0.143	-0.319
19	0.95	1.113	-0.175	-0.483
20	1.00	1.105	-0.205	-0.456
21	1.05			
22	1.10	1.083	-0.241	-0.510
23	1.15	1.068	-0.280	-0.564
24	1.20	1.053	-0.307	-0.442
25	1.25	1.037	-0.323	-0.339
26	1.30	1.021	-0.336	-0.317
27	1.35	1.004	-0.354	-0.316

Table 1.1.1 here is most of our data. Because our angle is 1.71 our calculated acceleration is sin(1.71)*-9.8=-0.294 m/s^2.

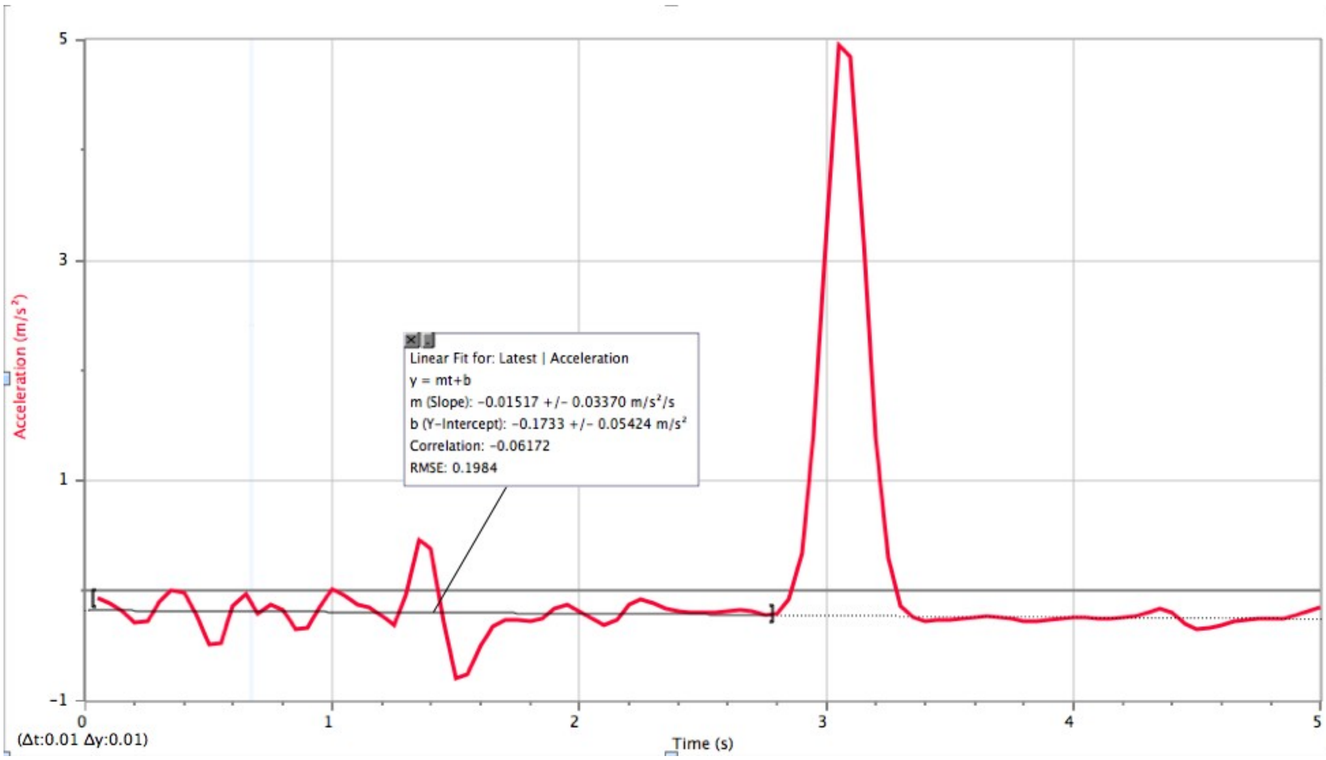
For the second trial the incline plane was set to 3.26°.



Graph 1.2.1 position graph for the second test. Again A is ½ acceleration so our observed acceleration is -0.596 m/s^2.



Graph 1.2.2 velocity graph for the second test. Yet again the slope of this graph is our acceleration, -0.585, who would have thought?



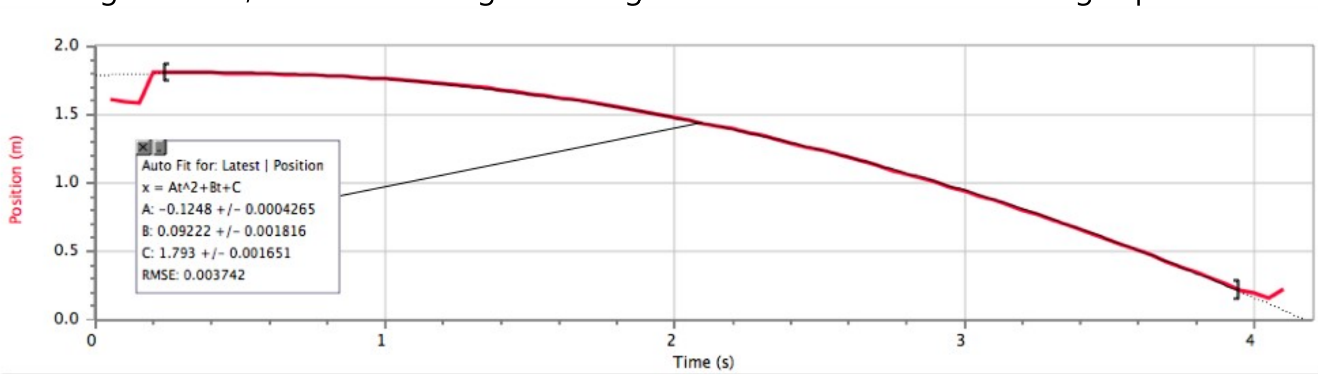
Graph 1.2.3 acceleration graph. Again this graph is so messed up our acceleration came out to be -.173 which is really off.

	Latest			
	Time (s)	Position (m)	Velocity (m/s)	acc (m/s^2)
1	0.05	0.964	-0.028	0.281
2	0.10	0.962	-0.013	0.215
3	0.15	0.962	-0.002	0.094
4	0.20	0.962	0.004	-0.145
5	0.25	0.964	-0.017	-0.387
6	0.30	0.960	-0.039	-0.537
7	0.35	0.961	-0.072	-0.626
8	0.40	0.954	-0.112	-0.536
9	0.45	0.948	-0.128	-0.389
10	0.50	0.941	-0.141	-0.376
11	0.55	0.935	-0.172	-0.272
12	0.60	0.922	-0.179	-0.028
13	0.65	0.915	-0.154	-0.169
14	0.70	0.910	-0.176	-0.653
15	0.75	0.900	-0.233	-0.879
16	0.80	0.886	-0.287	-0.685
17	0.85	0.869	-0.307	-0.375
18	0.90	0.854	-0.308	-0.351
19	0.95	0.839	-0.327	-0.617
20	1.00	0.823	-0.376	-0.810
21	1.05	0.801	-0.419	-0.800
22	1.10	0.781	-0.455	-0.769
23	1.15	0.756	-0.494	-0.757
24	1.20	0.731	-0.530	-0.750
25	1.25	0.703	-0.570	-0.725
26	1.30	0.674	-0.609	-0.592
27	1.35	0.642	-0.632	-0.415
28	1.40	0.610	-0.643	-0.367

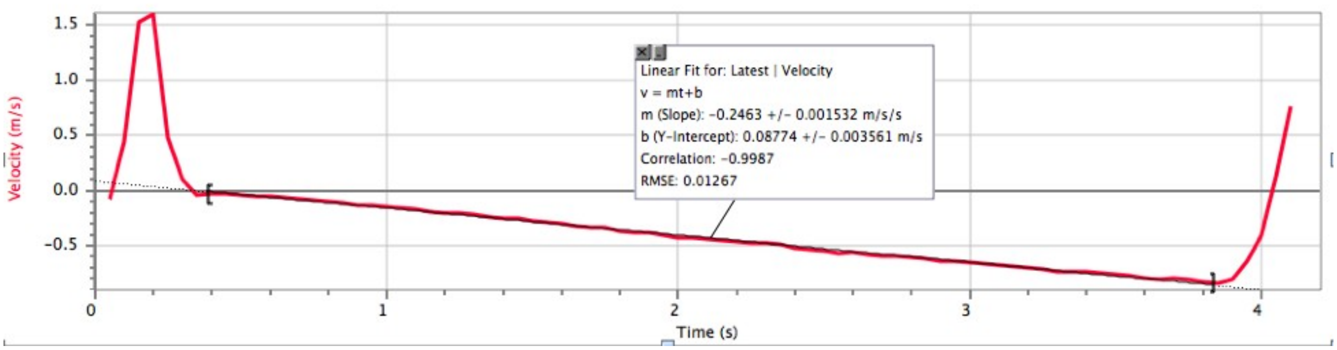
Table 1.2.1 here is most of our data. Because our angle is 5.26 our calculated acceleration is

sin(3.26)*-9.8=-.0557 m/s^2.

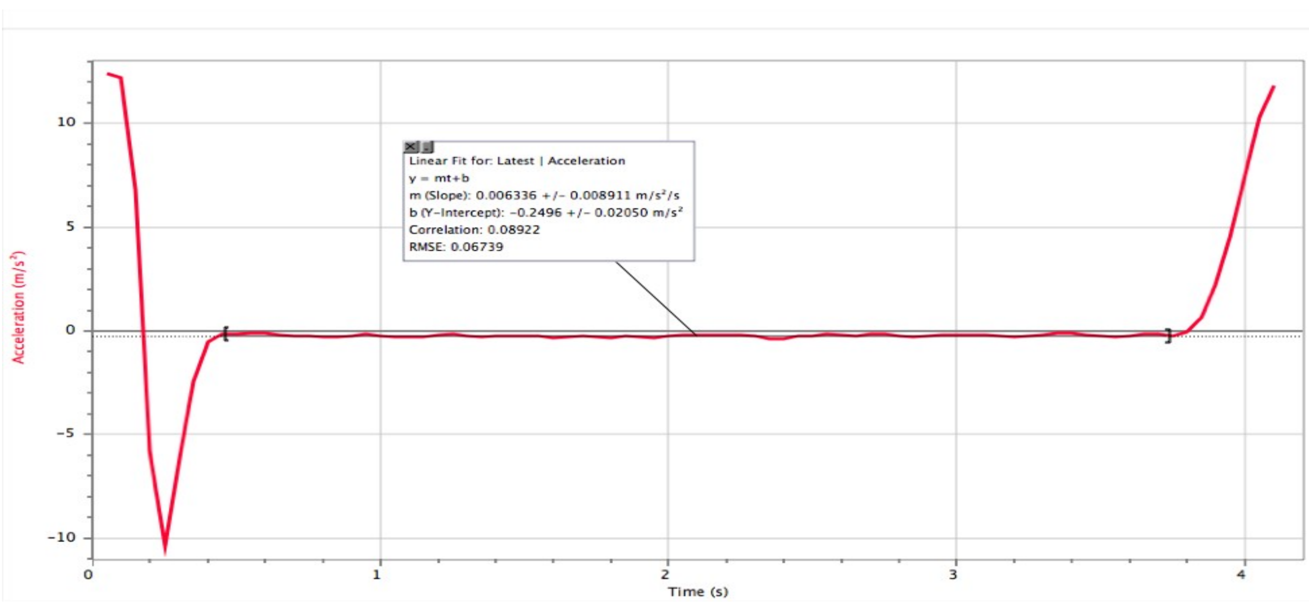
Fan Cart:
No weight added, so the total weight is 386 grams and the cart was set to high speed.



Graph 2.1.1 position graph for the cart. As with the incline plane the acceleration is 2*A so the acceleration is -.249.



Graph 2.1.2 velocity graph for the cart. Yet again the acceleration is the slope of this graph which is -.246.

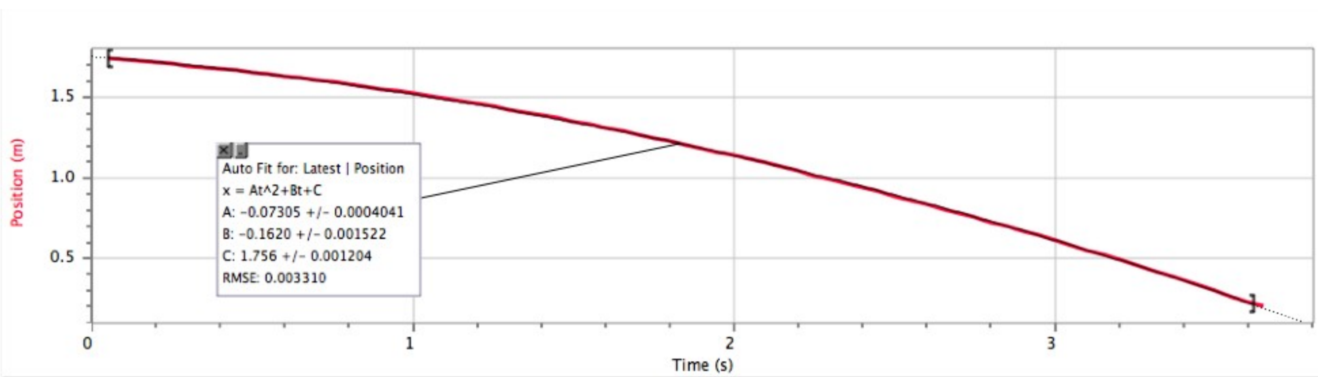


Graph 2.1.3 acceleration graph for the cart. The y intersection for this is -.249 which is the same as the other 2, finally all three are matching.

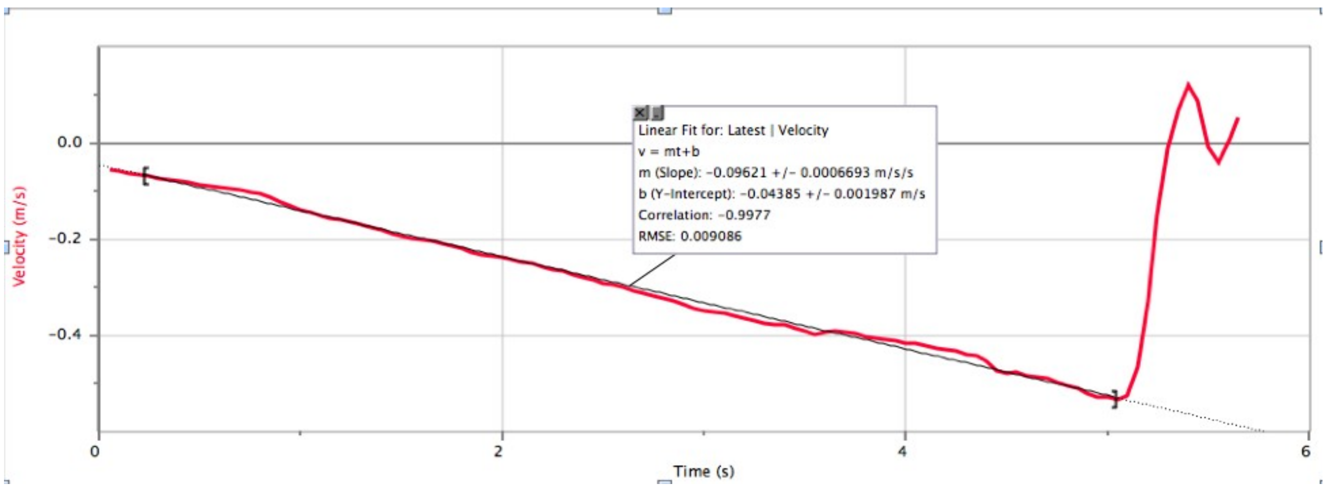
	Latest			
	Time (s)	Position (m)	Velocity (m/s)	acc (m/s^2)
1	0.05	1.617	-0.079	12.406
2	0.10	1.598	0.440	12.222
3	0.15	1.585	1.528	6.828
4	0.20	1.812	1.595	-5.777
5	0.25	1.812	0.481	-10.354
6	0.30	1.811	0.097	-6.164
7	0.35	1.809	-0.035	-2.428
8	0.40	1.807	-0.034	-0.527
9	0.45	1.806	-0.034	-0.160
10	0.50	1.804	-0.044	-0.138
11	0.55	1.801	-0.053	-0.106
12	0.60	1.798	-0.052	-0.106
13	0.65	1.796	-0.059	-0.187
14	0.70	1.793	-0.074	-0.225
15	0.75	1.788	-0.083	-0.234
16	0.80	1.785	-0.094	-0.285
17	0.85	1.780	-0.112	-0.312
18	0.90	1.774	-0.131	-0.238
19	0.95	1.765	-0.136	-0.170
20	1.00	1.760	-0.141	-0.227
21	1.05	1.752	-0.158	-0.302
22	1.10	1.744	-0.175	-0.316
23	1.15	1.735	-0.191	-0.289
24	1.20	1.725	-0.207	-0.210
25	1.25	1.713	-0.211	-0.166

Table 2.1.1 here is our data. So if F=ma then F=.386*-.249=-.09611N.

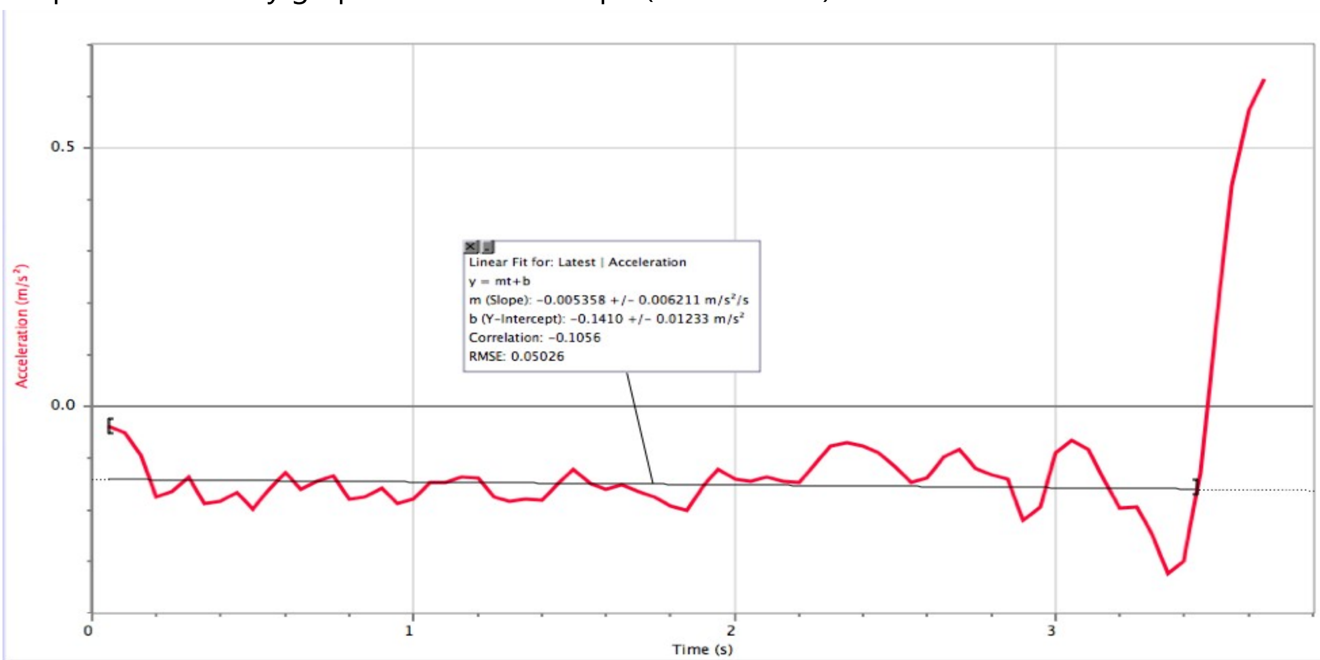
No weight added, so the total weight is 386 grams and the cart was set to low speed.



Graph 2.2.1 position graph for the cart. 2A(acceleration)=-.1461.



Graph 2.2.2 Velocity graph for the cart. Slope (acceleration)=-.0962.

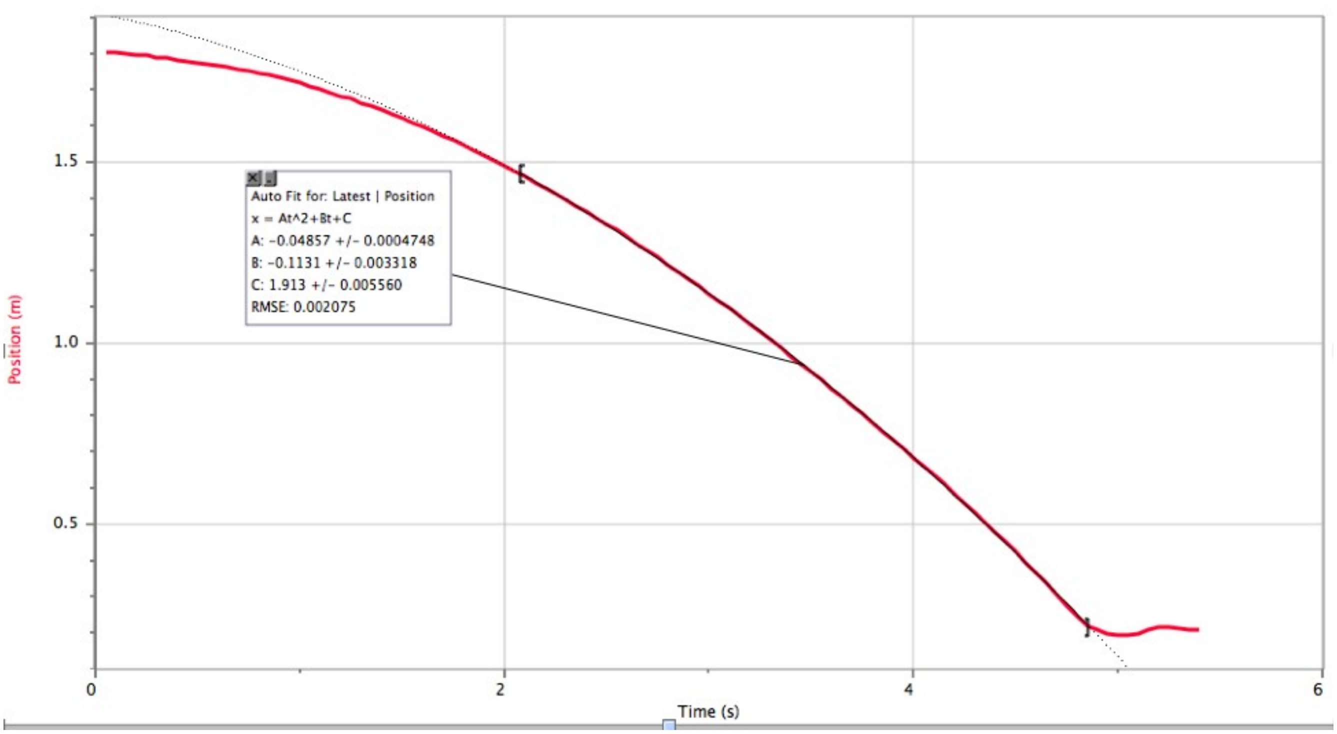


Graph 2.2.3 Acceleration for the cart. Y intercept (acceleration)= -.141.

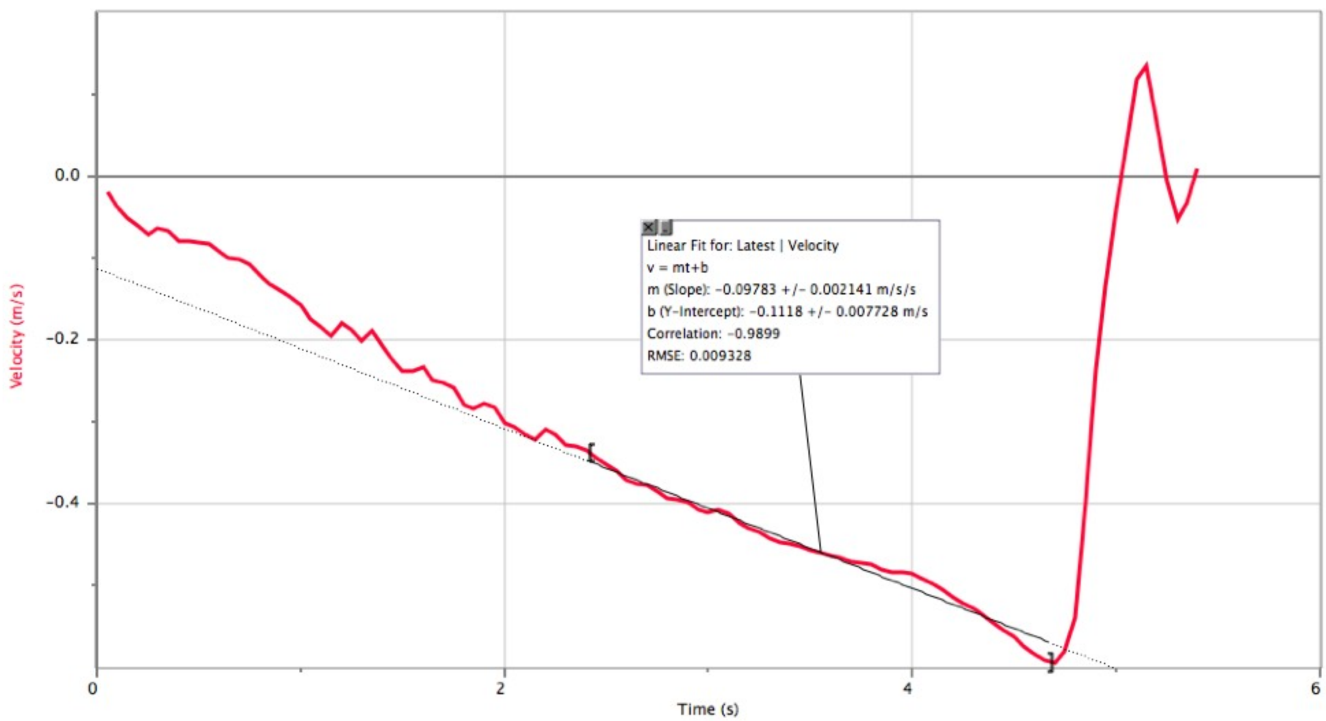
	Latest			
	Time (s)	Position (m)	Velocity (m/s)	acc (m/s^2)
1	0.05	1.741	-0.162	-0.038
2	0.10	1.733	-0.165	-0.050
3	0.15	1.725	-0.164	-0.094
4	0.20	1.717	-0.172	-0.175
5	0.25	1.708	-0.187	-0.165
6	0.30	1.698	-0.189	-0.137
7	0.35	1.689	-0.196	-0.188
8	0.40	1.679	-0.211	-0.184
9	0.45	1.667	-0.215	-0.166
10	0.50	1.657	-0.224	-0.198
11	0.55	1.645	-0.239	-0.163
12	0.60	1.633	-0.241	-0.128
13	0.65	1.622	-0.248	-0.159
14	0.70	1.608	-0.260	-0.146
15	0.75	1.595	-0.262	-0.134
16	0.80	1.582	-0.269	-0.179
17	0.85	1.568	-0.283	-0.176
18	0.90	1.553	-0.288	-0.159
19	0.95	1.540	-0.296	-0.189
20	1.00	1.524	-0.309	-0.179
21	1.05	1.508	-0.315	-0.146
22	1.10	1.493	-0.322	-0.147
23	1.15	1.476	-0.331	-0.137
24	1.20	1.459	-0.335	-0.138
25	1.25	1.443	-0.342	-0.175

Table 2.2.1 here's the data. So if F=ma then F=.386*-.141=-.0544N.

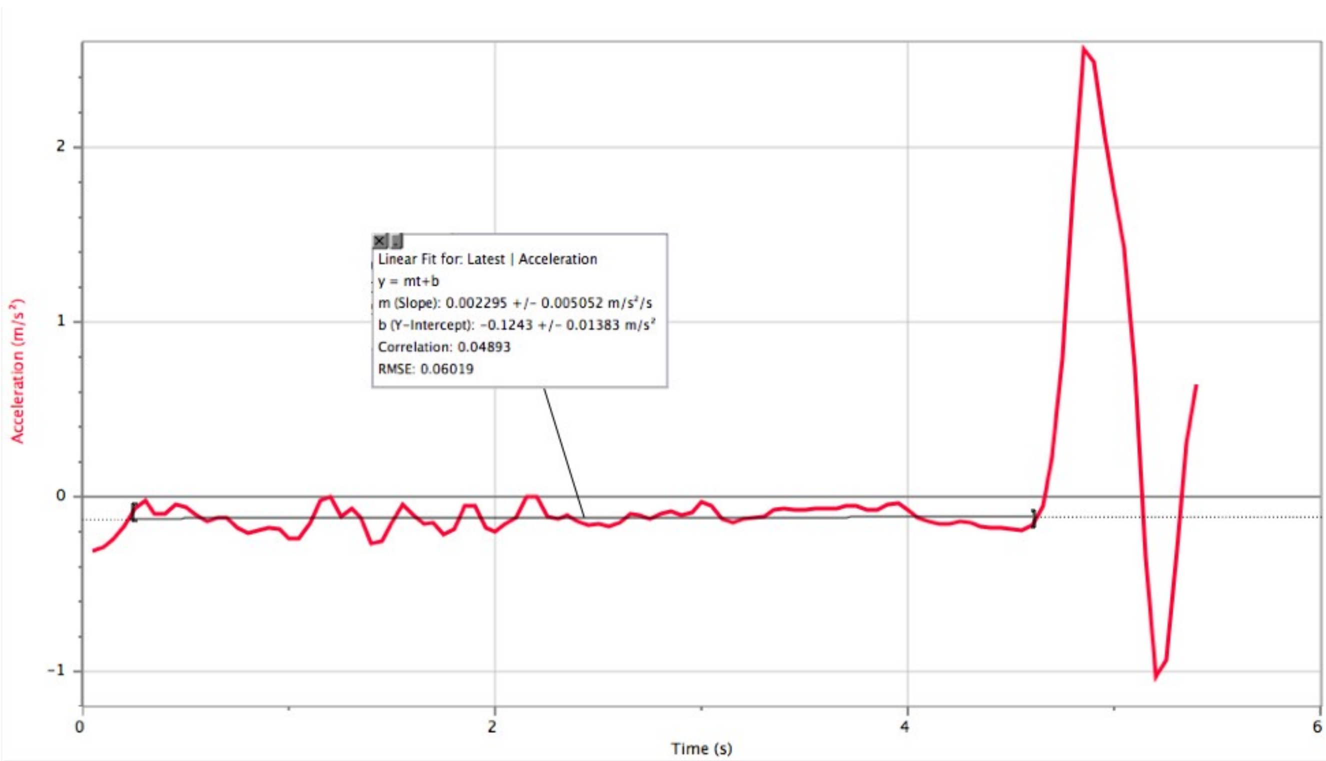
A small weight added, so the total weight is 676 grams and the cart was set to high speed.



Graph 2.3.1 position. 2A(acceleration)= -.09714.



Graph 2.3.2 velocity. Slope (acceleration)=-.0978.

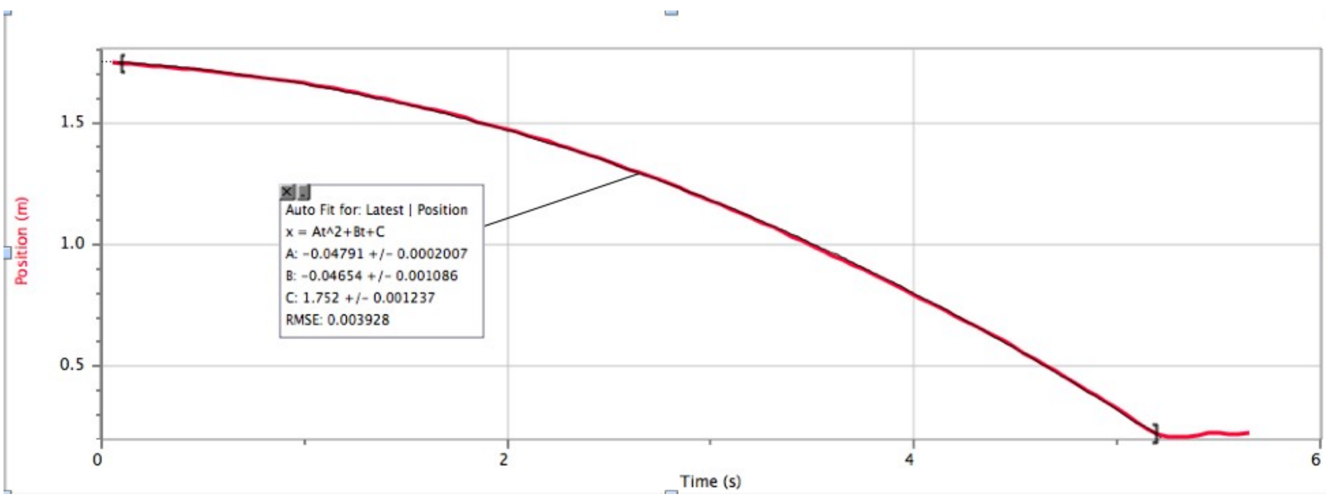


Graph 2.3.3 acceleration. Y intercept (acceleration)=-.124

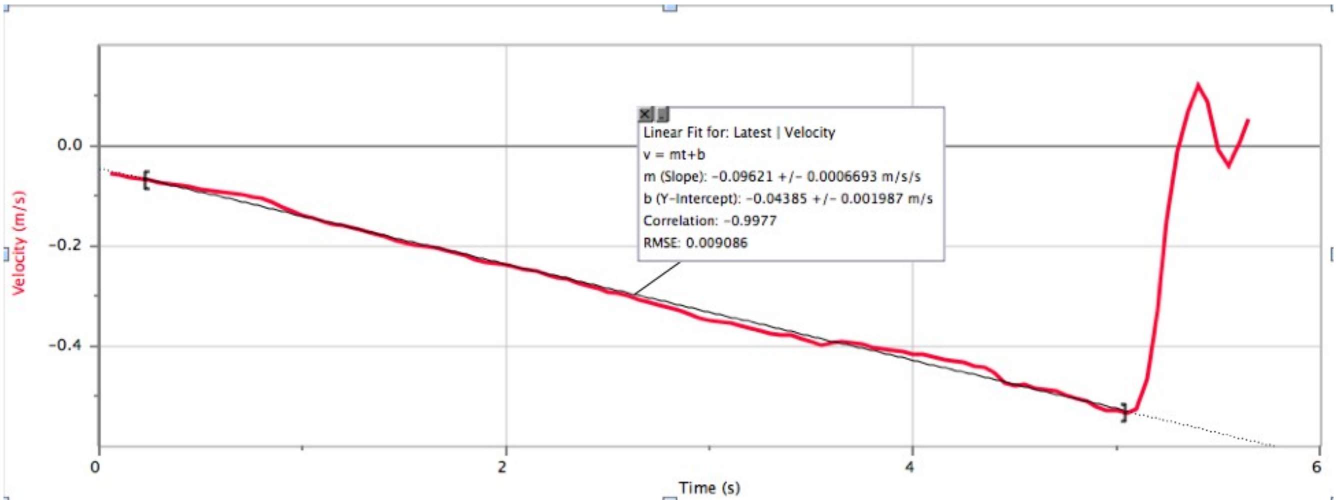
	Latest			
	Time (s)	Position (m)	Velocity (m/s)	acc (m/s^2)
1	0.05	1.803	-0.019	-0.315
2	0.10	1.802	-0.036	-0.293
3	0.15	1.799	-0.051	-0.239
4	0.20	1.797	-0.060	-0.175
5	0.25	1.794	-0.072	-0.066
6	0.30	1.789	-0.063	-0.020
7	0.35	1.788	-0.066	-0.101
8	0.40	1.783	-0.079	-0.095
9	0.45	1.779	-0.078	-0.047
10	0.50	1.775	-0.080	-0.057
11	0.55	1.771	-0.082	-0.104
12	0.60	1.767	-0.092	-0.140
13	0.65	1.762	-0.099	-0.117
14	0.70	1.757	-0.102	-0.121
15	0.75	1.752	-0.108	-0.176
16	0.80	1.746	-0.121	-0.210
17	0.85	1.740	-0.132	-0.195
18	0.90	1.733	-0.140	-0.176
19	0.95	1.726	-0.148	-0.190
20	1.00	1.718	-0.157	-0.239
21	1.05	1.711	-0.174	-0.237
22	1.10	1.700	-0.185	-0.159
23	1.15	1.692	-0.194	-0.021
24	1.20	1.680	-0.180	0.002
25	1.25	1.675	-0.187	-0.112
26	1.30	1.661	-0.202	-0.070
27	1.35	1.653	-0.188	-0.121
28	1.40	1.644	-0.207	-0.265
29	1.45	1.633	-0.224	-0.251

Table 1.3.1. So if F=ma then F=.676*-.09714=-.06566N.

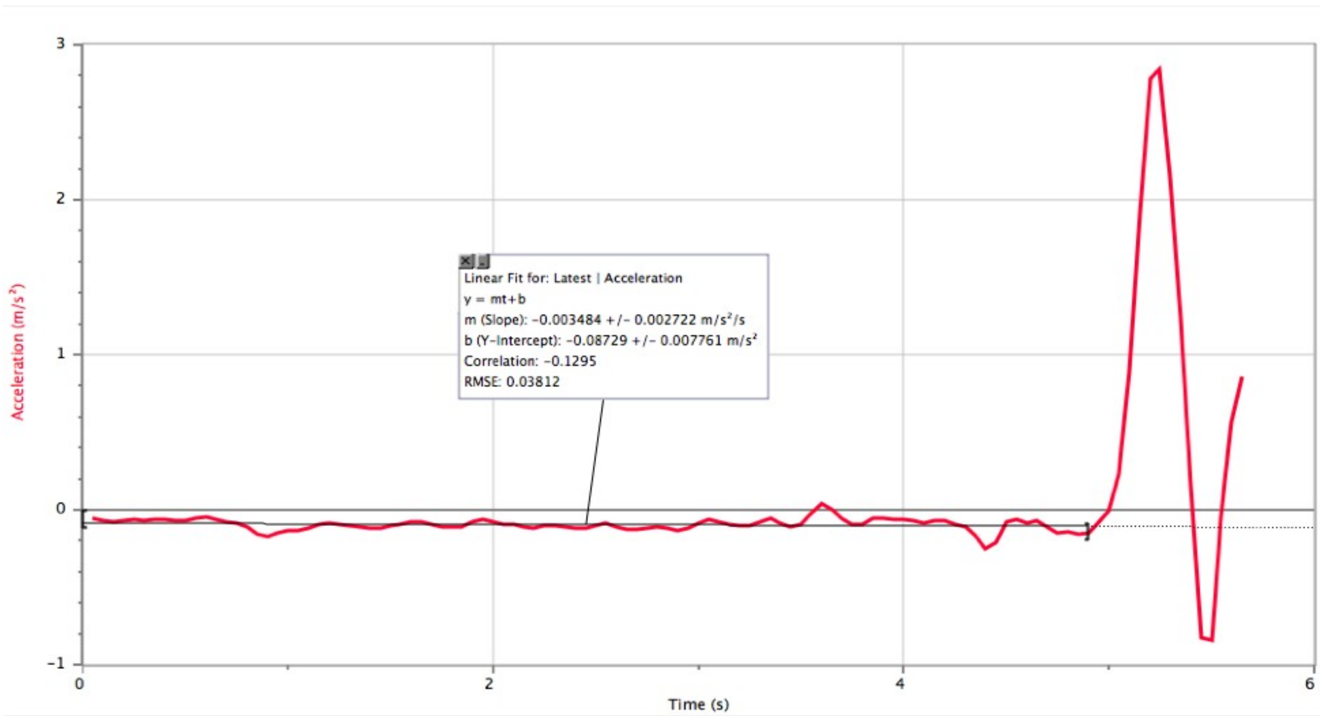
A small weight added, so the total weight is 676 grams and the cart was set to low speed.



Graph 2.4.1 position. 2A (acceleration)=-.09582



Graph 2.4.2 velocity. Slope (acceleration)=-.09621



Graph 2.4.3 acceleration. Y intercept (acceleration)=-.00348

	Latest			
	Time (s)	Position (m)	Velocity (m/s)	acc (m/s^2)
1	0.05	1.745	-0.056	-0.058
2	0.10	1.742	-0.058	-0.069
3	0.15	1.739	-0.062	-0.078
4	0.20	1.736	-0.067	-0.070
5	0.25	1.733	-0.069	-0.063
6	0.30	1.729	-0.072	-0.069
7	0.35	1.725	-0.077	-0.066
8	0.40	1.721	-0.079	-0.062
9	0.45	1.718	-0.082	-0.069
10	0.50	1.713	-0.086	-0.068
11	0.55	1.709	-0.090	-0.057
12	0.60	1.704	-0.092	-0.050
13	0.65	1.700	-0.094	-0.062
14	0.70	1.695	-0.098	-0.079
15	0.75	1.690	-0.102	-0.086
16	0.80	1.685	-0.105	-0.111
17	0.85	1.680	-0.112	-0.155
18	0.90	1.674	-0.123	-0.169
19	0.95	1.667	-0.131	-0.151
20	1.00	1.660	-0.137	-0.136
21	1.05	1.653	-0.144	-0.130
22	1.10	1.646	-0.151	-0.116
23	1.15	1.638	-0.156	-0.096
24	1.20	1.630	-0.160	-0.090
25	1.25	1.622	-0.164	-0.093

Table 2.4.1. So if F=ma then F=.676*-.09582=-.06477N.

Observations:

Incline Plane

If you look at all of our graphs our RMSE is very low around 3%, except for the one acceleration graph where we did not limit the data so it got a lot of weird results. This is great accuracy and it is reflected in our error calculation. The only way we could have gotten a better result was to somehow get a true frictionless cart and do this experiment in a vacuum.

Fan Cart:

Our RMSE for this lab was really low, about 5% this was because we used the sonic range finder. Unfortunately something went horrible wrong and our results were very weird.

Analysis:

Incline Plane:

Our error for this lab was very low. For the first incline plane we calculated that acceleration should be .294 m/s^2 and our measured acceleration is .304 m/s^2 so our error is -3.4% which is fantastic. For the second test our calculated acceleration is .602 m/s^2 and the measured acceleration was .596 m/s^2 so our error is -1.0%. So this experiment proves that sinθ g=gravity.

Fan Cart:

This experiment did not go as well. Our calculated forces for the high setting was

-.096N for the empty cart and -.065N with a weight added to it, this is really bad. For the low setting the calculated forces are -.0544N for a empty cart and -.0647 for a small weight added. That was a lot better but they should have been much closer. That is because the force from the fan is constant so as mass increases acceleration decreases but they are proportional so it should have stayed the same. Unfortunately this lab has some conflicting results, we would have to use a more reliable device. Possible sources of error include the battery dying, a small breeze pushing the cart. However the biggest source of error would be a mis calculation doing the curve fit for one of our graphs, we included a big jump in a graph so it caused everything after that to be off.

Conclusion:

Overall half this lab went as expected. We had some difficulty with the fan cart section. However the incline plane part was a complete success. Our results matched perfectly with our expected outcomes. If I were to do this in college again I would try to find a better way to do the fan cart part.