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Force and Acceleration

Purpose:

To learn more about the relationship between mass, force, and acceleration by proving that a system with constant force and more mass will accelerate slower and a system of constant mass with a greater force will accelerate quicker.

Procedure:

This lab had two parts. Before we began, we set up a smart cart track at the edge of a table and attached a super pulley to the end of it so that it hung over the table. We then ran a thin string from the cart over the pulley and down the side of the table towards the floor as seen in figure 1, which was connected to a paperclip holding a 5g mass. From there, we began taking data for part A by releasing the system from rest and measuring its time speed and distance. We took three trials and then added 250g to the cart. We again took three trials of data and added an extra 250g for a total of 500g added to the cart and took three more trials. We used these data sets to calculate the acceleration of the system in each case. For part B, we used the same set up, but instead took 5 2g masses and put one on the paperclip for a total hanging mass of 2g plus the weight of the clip, and put the other four 2g masses in the empty cart. We took three trials in this configuration and transferred one 2g mass from the cart to the clip, thus increasing the force while keeping the mass of the system the same. We took three trials and continued in this process until our cart was empty. We again used the data collected to calculate the acceleration of the system.

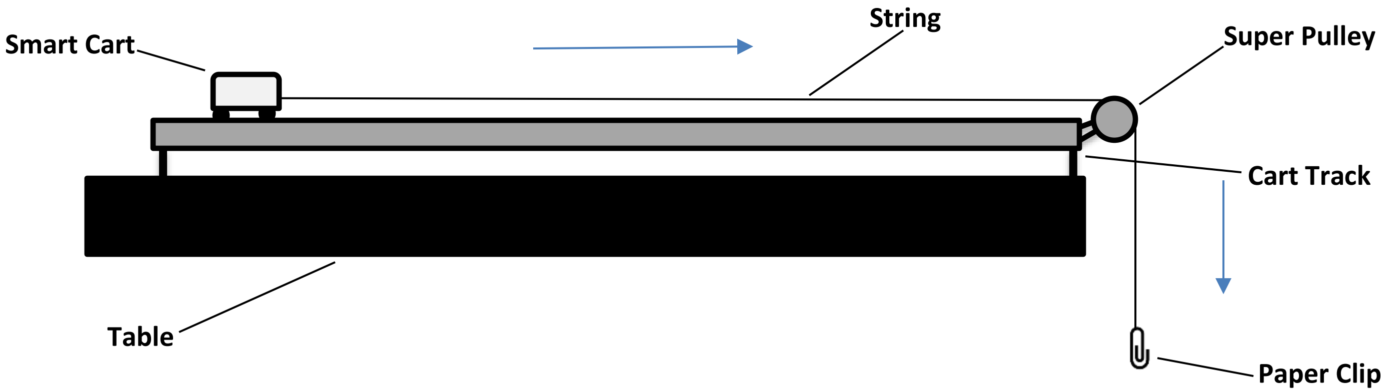

Figure 1. Smart Cart Force Track

Table 1. Lab Equipment

Equipment	Serial Number
Smart Cart	Blue 319-097
Smart Cart Track	Biola #2

Data: Table 2. Raw Data

Cart	Trial	m1[g]	m2 [g]	t1 [s]	x1 [m]	v1 [m/s]	t2 [s]	x2 [m]
Part A								
Empty	1	269.5	5.5	1.35	0.0029	0.049	3.6	0.5417
	2	269.5	5.5	1.05	0.0011	0.027	3.45	0.5572
	3	269.5	5.5	0.25	0.0061	0.049	2.55	0.553
250	1	519.5	5.5	0.85	0.0015	0.016	4.25	0.5564
	2	519.5	5.5	1.05	0.0013	0.016	4.35	0.551
	3	519.5	5.5	1.05	0.0012	0.013	4.45	0.5698
500	1	769.5	5.5	0.75	0.0012	0.01	4.9	0.5605
	2	769.5	5.5	0.9	0.0016	0.013	5.1	0.5713
	3	769.5	5.5	0.3	0.0016	0.017	4.25	0.5048
Part B								
Add 8g	1	277.5	2.5	0.55	0.0013	0.006	6.55	0.554
	2	277.5	2.5	0.55	0.0013	0.01	6.15	0.5246
	3	277.5	2.5	0.2	0.0017	0.016	5.45	0.5594
Add 6g	1	275.5	4.5	0.2	0.0013	0.015	4.15	0.5543
	2	275.5	4.5	0.5	0.0012	0.012	4.3	0.5527
	3	275.5	4.5	0.5	0.0013	0.018	4.35	0.5591
Add 4g	1	273.5	6.5	0.65	0.0017	0.017	3.7	0.5544
	2	273.5	6.5	0.2	0.0019	0.023	3.25	0.563
	3	273.5	6.5	0.6	0.0011	0.016	3.7	0.5589
Add 2g	1	271.5	8.5	0.45	0.0011	0.018	3.15	0.5595
	2	271.5	8.5	0.2	0.0016	0.022	2.85	0.5596
	3	271.5	8.5	0.35	0.0015	0.018	3	0.5527
Add 0g	1	269.5	10.5	0.25	0.0012	0.011	2.7	0.5669
	2	269.5	10.5	0.75	0.0016	0.019	3.15	0.5584
	3	269.5	10.5	1.5	0.0015	0.022	3.9	0.5566

Results: Table 3. Calculated Results

Cart	*Trial*	dt (s)	dx (m)	a (m/s^2)	g (m/s^2)
Part A					
Empty	1	2.25	0.5388	0.17	8.47
	2	2.4	0.5561	0.17	8.53
	3	2.3	0.5469	0.16	8.21
250	1	3.4	0.5549	0.09	8.27
	2	3.3	0.5497	0.09	8.71
	3	3.4	0.5686	0.09	8.66
500	1	4.15	0.5593	0.06	8.47
	2	4.2	0.5697	0.06	8.23
	3	3.95	0.5032	0.06	7.88
Part B					
Add 8g	1	6	0.553	0.03	3.22
	2	5.6	0.523	0.03	3.34
	3	5.25	0.558	0.03	3.85
Add 6g	1	3.95	0.553	0.06	3.94
	2	3.8	0.552	0.07	4.36
	3	3.85	0.558	0.07	4.10
Add 4g	1	3.05	0.553	0.11	4.64
	2	3.05	0.561	0.11	4.55
	3	3.1	0.558	0.11	4.56
Add 2g	1	2.7	0.558	0.14	4.61
	2	2.65	0.558	0.14	4.69
	3	2.65	0.551	0.14	4.72
Add 0g	1	2.45	0.566	0.18	4.79
	2	2.4	0.557	0.18	4.73
	3	2.4	0.555	0.17	4.65

Graphs:

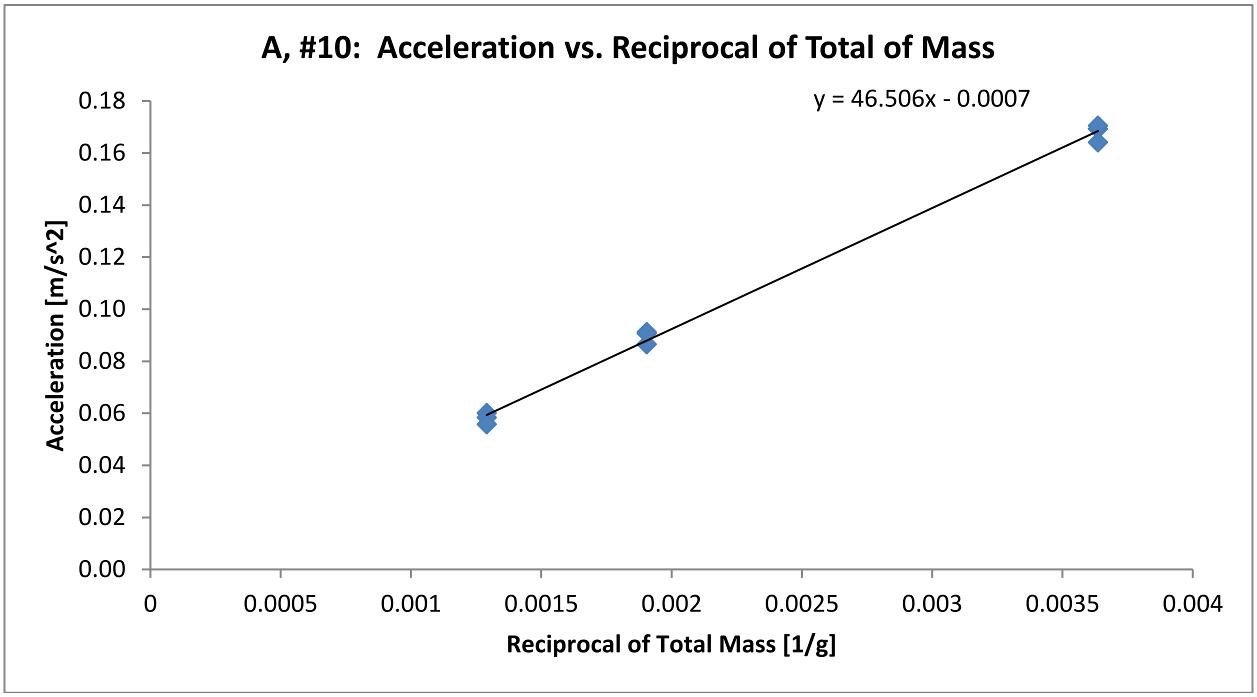

Figure 2. Plot of calculated acceleration and reciprocal of mass

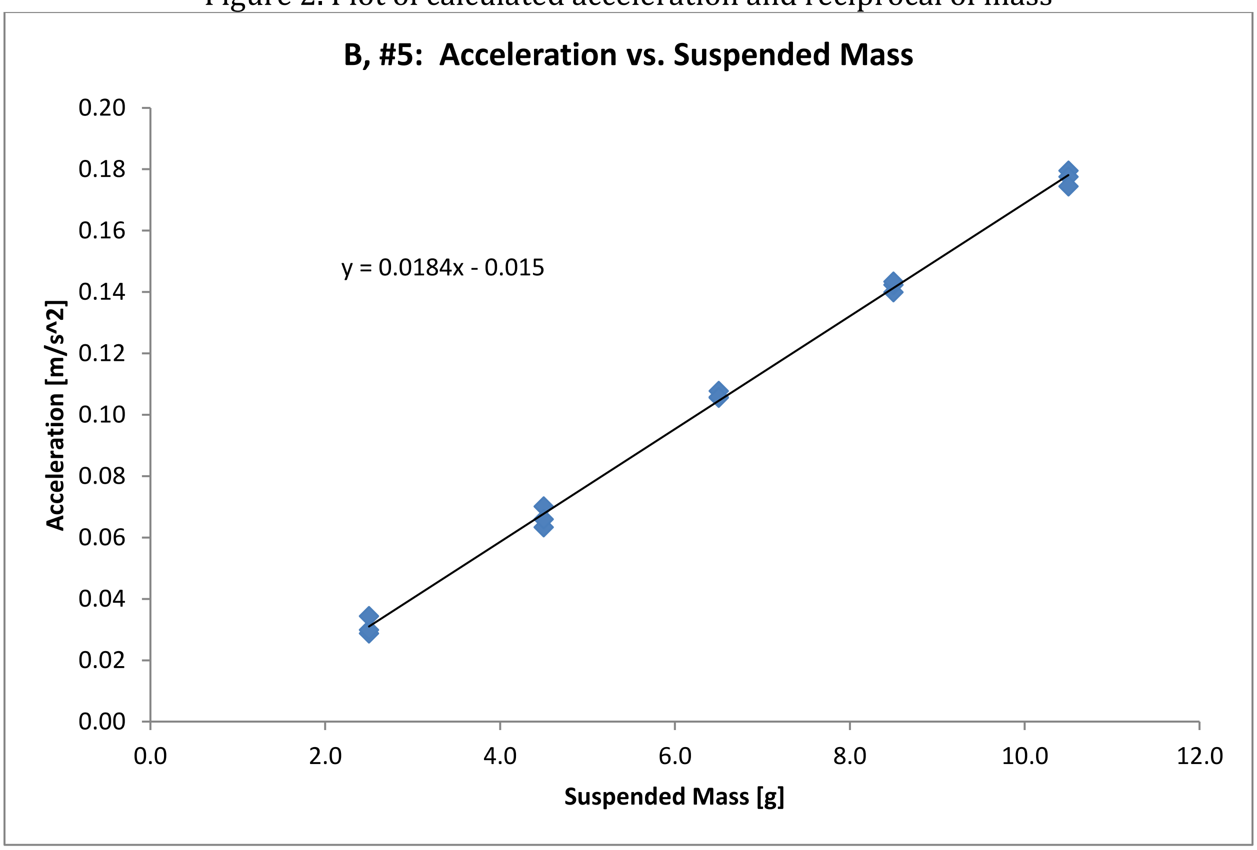

Figure 3. Plot of calculated acceleration and amount of mass hanging

Calculations:

Δt = t2 – t1
= 3.60s – 1.35s
= 2.25s

Δx = x2 -x1
= 0.5417m – 0.0029m
= 0.5388m

$$a = \frac{2(\Delta x - v_{init}\Delta t)}{\Delta t^2}$$
$$= \frac{2(0.5388m - \left(\frac{0.049m}{s}\right)2.25s)}{(2.25s)^2}$$
$$= \frac{2(0.42855m)}{5.0625s^2}$$
$$= \frac{0.1693m}{s^2}$$

$$\boldsymbol{g = \frac{(m_1 + m_2)a}{m_2}}$$
$$\boldsymbol{= \frac{(269.5g + 5.5g)\left(\frac{0.1693m}{s^2}\right)}{5.5g}}$$
$$\boldsymbol{= \frac{46.5585g * \frac{m}{s^2}}{5.5g}}$$
$$\boldsymbol{= \frac{8.465m}{s^2}}$$

Questions:

1. %error = ((Exact Value – Experimental Value)/Exact Value)*100
   = ((9.8 – 8.38)/9.8)*100
   = 14.49 %error
2. The largest source of error in this lab is friction because we know that Gravity is $9.8 m/s^2$, but we keep getting values consistently lower than this. The graph helps us work around this by showing us that the force of friction is constant and revealing that the acceleration of our cart is still constant because we can see a constant slope.
3. This lab was rather easy to work through and we were able to set it up and execute the measurements relatively quickly. The only suggestion I have is that the lab tables divide up the work more efficiently. My lab group took different jobs and got finished very quickly, but I noticed other groups going slowly because they did one task at a time.
4. (See Notebook)
5. In part A, we kept the force on the cart constant and varied the mass of the system. In part B, we kept the mass of system constant while varying the force on the cart.
6. We can see that Force = Mass * Acceleration based on figure 2. because the slope of the graph – Roughly 46 – gives us the product of the mass of the system and the acceleration we calculated for it. Thus, mass times acceleration is our force.

Conclusion:

In this lab, we were able to prove that a system of constant mass and constant force will produce a constant acceleration over its distance of travel. Our graphs, having a very even and straight distribution, prove that as we increase the force on a system, the acceleration increases, and as the mass of the system increases, the acceleration decreases. These two factors being proportional prove that F=ma. The slope of graph in figure 2 signifies the force on the system in Newtons, and the slope of the second graph shows the constant rate at which acceleration increases proportionally to force. We were able to achieve our purpose because our graphs clearly show the relationship between force, mass, and acceleration which we were trying to prove.

Our main sources of error can most likely be attributed to friction in the system. We know the value of gravity, yet we calculated it to be much less because the force of friction counter-acts movement. Overall, we had a relatively small margin of error, however, I believe that there could be more friction eliminated if we used air tracks instead of carts. In order to improve this experiment, I would use a longer track to ensure a long collection time for the data, and I would use air tracks instead of cart tracks to eliminate some friction from the system.