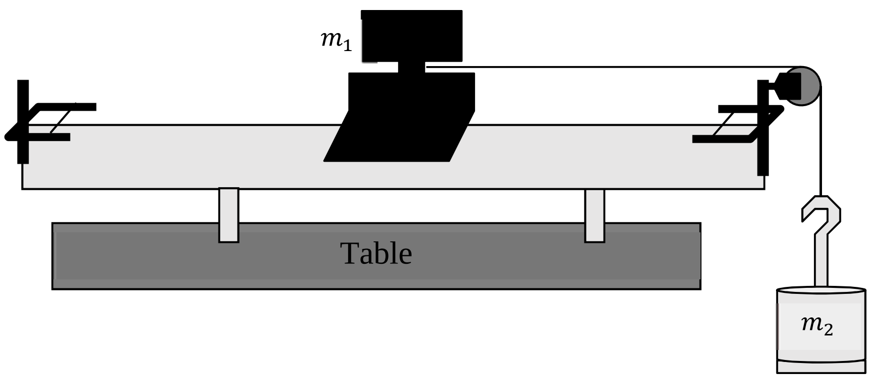
Newton's Second Law Part I

Apparatus: Air track glider (1 per track), air tracks, air supplies, air supply hoses & power cords, air track accessories kits, scissors, pulley cord, stopwatches, balances, meter sticks.

Purpose: To gain additional practice drawing force diagrams and solving force problems using Newton's 2nd Law. To predict and measure the acceleration of a cart on a level track when pulled by a hanging mass.

Procedure:

1. **Level track**. Level the air track by using the adjustable legs. To be sure it is level place a cart on the leveled air track at rest. If it starts moving it is not quite level. Check it both in the middle of the track and at the ends of the track. Try to get air track as level as possible because small differences can cause large percent errors in today's lab.



- Remove the four 50 g masses (they look like short, shiny, cylinders with holes in the middle) from the air track accessories kit and place two on each side of your glider.
- Tie a piece of string to the glider/cart so that m_2 is touching the ground and the glider/cart is close to (but not yet touching) the stopper closest to the pulley.
- To determine how far the system will travel (x), all you need to do is pull the glider a known distance away from the pulley. Use a convenient distance like 0.500 m.
- **The values of m_2 you should use for this lab are <u>about</u> 4, 6, 8, 10, and 12 grams.** Determine the masses by using the balances in the classroom. **<u>Don't forget to account for the mass of the hanger (approx. 2 grams).</u>**
- Start with the smallest m_2.
- Release the cart from rest when m_2 is at the top and listen for the sound of m_2 hitting the ground.
- Time how long it takes for m_2 to hit the ground. That is also the time for the cart to travel a distance x. The time t for the m_2 to hit the ground should be on the order of seconds.
- For each m_2, record the time for each of five trials (note: the distance is x for each trial). You should now have 5×5=25 times recorded.
- Think: How should the times change as mass increases (longer, same, and shorter)? How should your predicted value of acceleration change (bigger, same, and smaller)? What does the experimental result show?
- Record the mass of the glider INCLUDING any attachments that were on it during the experiment. Will this be m_1 or m_2?

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- For your calculations section, use kinematics to determine an equation for the experimental acceleration a_{exp} from this x and t data. Write the formula in your notes and define each variable in the introduction section. Solve for a_{exp} algebraically then show an explicit calculation for one case (you do not have to show all a_{exp}'s by hand).
- Tabulate all a_{exp}'s in your data table.
- Get an average value of a_{exp} and the standard deviation of a_{exp}.
- Determine the %precision of a_{exp}. If the standard deviation is exceedingly use propagation of errors of sig fig rules to determine your precision.
- In your calculations section, draw a free body diagram for the cart.
- Draw a separate free body diagram for the hanging mass.
- Write down the forces in both the *x* and *y* directions for both FBD's.
- Then, using Newton's laws, determine an expression for the theoretical acceleration of the system. You should end up with only the variables m_1, m_2, and g. Write the formula in your notes and define each variable in the introduction section. Hint: the answer is of the form $a_{th} = g\frac{?}{?+?}$.
- Show an explicit calculation of a_{th} for one m_2 (not all).
- Calculate the %difference between the prediction (theory) value and the experimental value. Show this %difference in your table as well.
- Make a plot of a versus m_2. Show both the theoretical and experimental values of a. I call this a Type 2 Graph. This playlist has helpful training vids.

In your calculation section you should have:

Derivation of a_{exp}
Sample calc of a_{exp}
Derivation of a_{th}
Sample calc of a_{th}
Sample calc of %prec of a_{exp}
%difference calculations

Conclusions:

1. Were Newton's laws in good agreement with kinematics? Compare the %precision to the %difference.
2. Which measurement was the leading contributor to your errors: $m_1, m_2, t, or\ x$? For example, when you measured the masses you obtained many sig figs. This indicates the percent error is very small for the masses. Note: the percent error in m_1 is given by $\delta m_1/m_1 \times 100\%$. Improving your measurement of the masses will not lead to results that are significantly more precise. That implies they are not the leading contributor to error.
3. Which measurements had errors that were negligible when compared to the largest contributor to error?
4. What techniques of measurement or methods of performing the experiment could you employ to reduce the largest contributor to error? Assume you have ample budget to pay for technology required.
5. To make sure your formula for the theoretical acceleration is correct, consider the case of $m_1 = 1$ kg while $m_2 = 0$ (and the opposite case: $m_1 = 1$ kg while $m_2 = 0$). Think: what should the acceleration be in those cases? Write down the limiting result for a_{th} for *both cases* and explain why each makes sense.

Going Further: Create a contour plot in MATLAB showing the acceleration as m_1 and m_2 both vary. Perhaps let $m_1 = 0\ \text{ to }\ 400$ g and $m_2 = 0\ \text{ to }\ 40$ g.