Lab: Acceleration on an Inclined Plane

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Introduction:

The objective of this lab is to find the acceleration of a cart traveling on an inclined plane and compare the measured result to the expected value to see the percentage error. In this lab, the cart will be released on an inclined track from various known distances away from a photogate sensor placed toward the bottom of the track. The velocity of the passing cart will be measured through the sensor. The angle of the inclined plane will also be changed by increasing the height and data collection will be repeated to find the acceleration of the cart at the new angle

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Procedure:

The following steps will be executed:

1. Create an incline plane by resting one side of a cart track on three books
2. Measure two sides of the triangle that is formed between the books, table, and track. The measurements will be used later during analysis to find the angle the track makes with the horizontal plane.
3. Adjust the height of the velocity sensor so that the post on the cart passes through it and registers a reading.
4. Release the cart from a location at which the post is a known distance from the center of the photogate sensor. Not the speed with which the cart travels through the velocity sensor. To reduce measurement error, multiple measurements of velocity will be taken from the same release point and averaged together.
5. Repeat the experiment but add a book to the incline to increase the incline height.

Data Collection: ▯

Incline 1: 3 Books

Distance (m)	**Velocity Trial 1 (m/s)**	**Velocity Trial 2 (m/s)**	**Velocity Trial 3 (m/s)**	**Average Velocity (m/s)**

0.98	1.412	1.442	1.424	1.426
0.68	1.182	1.116	1.141	1.146
0.50	0.974	0.989	0.973	0.979
0.40	0.891	0.897	0.886	0.891
0.30	0.776	0.769	0.782	0.776
0.20	0.625	0.638	0.626	0.630

Important Measurements:

- Horizontal Base: 1.22 m
- Vertical Height of Incline: 0.16 m
- Angle theta (θ) = arctan(0.16/1.22) = 7.47 degrees

Incline 2: 4 books

Distance (m)	**Velocity Trial 1 (m/s)**	**Velocity Trial 2 (m/s)**	**Velocity Trial 3 (m/s)**	**Average Velocity (m/s)**
0.98	1.650	1.615	1.714	1.660
0.68	1.364	1.308	1.365	1.346
0.50	1.130	1.130	1.170	1.143
0.40	1.015	1.046	1.035	1.032
0.30	0.868	0.845	0.881	0.865
0.20	0.688	0.696	0.677	0.687

Important Measurements:

- Horizontal Base: 1.22 m
- Vertical Height of Incline: 0.21 m
- Angle theta (θ) = arctan(0.16/1.22) = 9.77 degrees

Data Analysis:

When approaching this problem, the data needed to be linearized in an organized fashion in order for the scientists to calculate the acceleration from these graphs alone. Linearization is the process of turning a quadratic relationship into a linear relationship by graphing the square of specific variables. Linearization can therefore be used for easier analysis because of the graph's transformation into a linear relationship.

To linearize the data, the following kinematic equation was used:

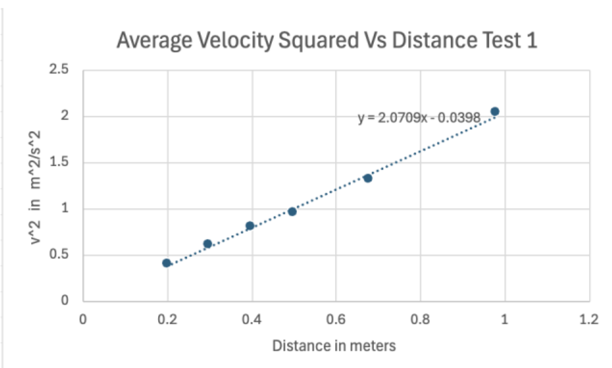
$V_f^2 = v_0^2 + 2a\Delta x$

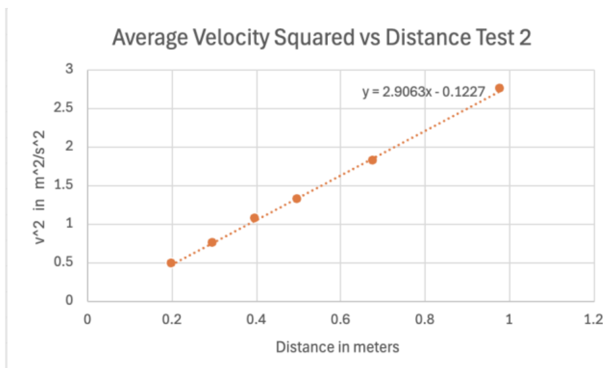
This equation represents a way to derive the acceleration (a) based on the final velocity (V_f) and total displacement (Δx). The reason why the initial velocity (v_0) is negligible is because the initial velocity is going to be 0 m/s because the object is starting from rest on top of the inclined plane.

Therefore, if the initial velocity is 0, the equation can then be simplified to:

$V_f^2 = 2a\Delta x$

The standard form of a linear graph is y = mx + b, where y is the output, m is the slope and b are the y-intercept. Furthermore, the variable y can be associated with final velocity squared (V_f^2) and the variable x can be associated with the displacement on the x-axis. Therefore, the slope of the line of best fit would be 2a. The final graphs are shown down below:





Test 1 is an experiment where 3 books (incline 1) were used while test 2 is the experiment where 4 books were used (incline 2).

A table is shown below organizing the values and their corresponding variables:

(V_f^2) Final velocity squared	2a – 2 * acceleration	Δx -- Displacement
y -- output	m -- slope	x – input (distance)

Calculations:

As mentioned before, the value 2a corresponds with the slope of the line of best fit. Therefore, to calculate the experimental acceleration, the slope of the line of best fit must be halved. All the major calculations in this study are shown in the table below:

Incline	Experimental Acceleration (m/s^2)	Height (m)	Horizontal Base (m)	Equation	Incline Angle (in degrees)	Theoretical Acceleration (m/s^2)
1	1.03545	0.16	1.22	gsin(θ)	$\tan^{-1}$ (0.16/1.22) = 7.47	9.8 * sin(7.47) = 1.27407
2	1.45315	0.21	1.22	gsin(θ)	$\tan^{-1}$ (0.21/1.22) = 9.77	9.8 * sin(9.77) = 1.663

The percentage error for incline 1 was around 23.5% while the percentage error for incline 2 was around 14.4%.

Conclusion:

In conclusion, the data presents reasonable acceleration with a percentage error of less than 50%. This experiment recorded an experimental acceleration of 1.03545 m/s^2 for the first incline, while it also recorded a theoretical acceleration of 1.27047 m/s^2. For the second incline, the experiment recorded an experimental acceleration of 1.45315 m/s^2 but calculated a theoretical acceleration of 1.663 m/s^2. According to the results, there was definitely a margin of error when comparing the experimental acceleration and the theoretical calculated acceleration. Specifically, the experimental acceleration was consistently lower than the theoretical acceleration, meaning that the acceleration could be smaller due to the force of friction. Since the equation a = gsin(θ) doesn't account for the impeding force of friction, it would make sense that the theoretical acceleration would be higher than the measured acceleration. This theory also branches off the incorrect assumption of the force of friction being negligible, when it in fact isn't. Another reason that could lend support to the presence of friction is that the wheels of the cart weren't perfectly aligned with the grooves of the ramp. If the cart's wheels were perfectly aligned with the grooves in an ideal scenario, then the force of friction acting upon the cart's wheels would be 0. However, this is not the case because there might be some minor inconsistencies with the cart not aligning with the grooves of the ramp, causing the force of friction to increase.