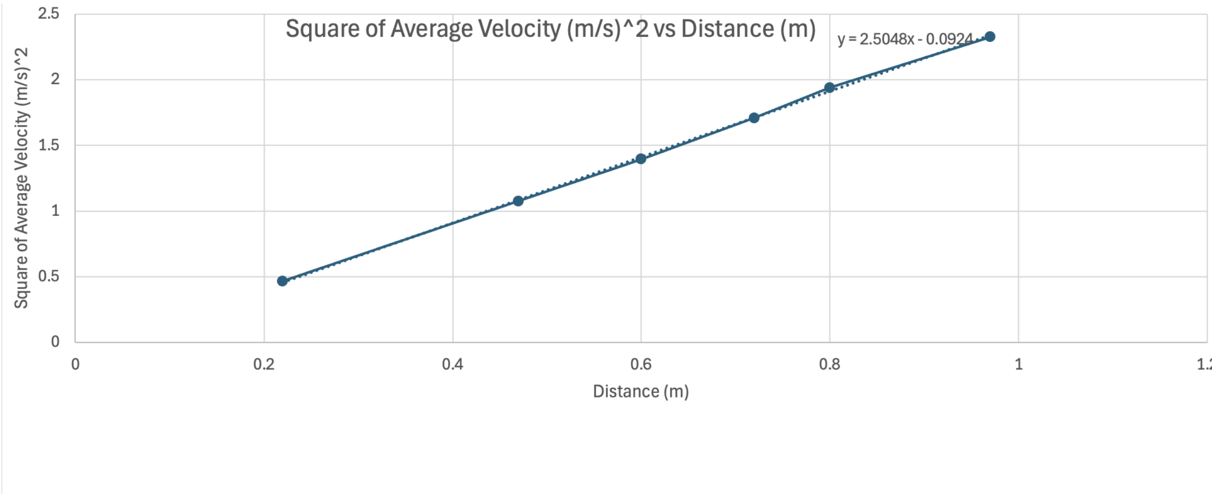
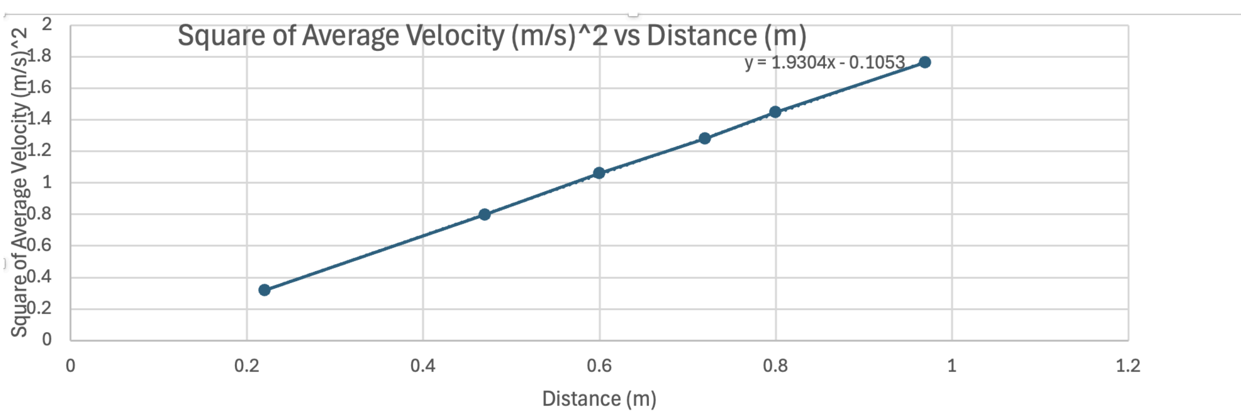
Rishi Gandhi - Acceleration on an Inclined Plane Lab

Trial 1:



Trial 2:



Procedure 1 line of best fit: $v^2 = 2.5048\,x - 0.0924$

Procedure 2 line of best fit: $v^2 = 1.9304\,x - 0.1053$

Analysis

For both inclines, the velocity of the cart was measured at various distances from the photogate, and a linearized graph of v^2 versus Δx was constructed. The relationship between the final velocity v of an accelerating object and displacement Δx is given by the following kinematic equation:

$v^2 = v_0^2 + 2\,a\,\Delta x$

Because the cart was released from rest, $v_0 = 0$, and the equation simplifies to:

$v^2 = 2\,a\,\Delta x$

This means that a plot of v^2 (m^2/s^2) on the y-axis versus Δx (m) on the x-axis should yield a straight line, where the slope of the line is equal to 2a. The acceleration of the cart can then be found by dividing the slope by 2.

Procedure 1: The line of best fit was:

$v^2 = 1.9304\,\Delta x - 0.1053$

Slope = 1.9304
$a = \text{slope} \div 2 = 1.9304 \div 2 = 0.9652\ m/s^2$

Procedure 2: The line of best fit from the spreadsheet was:

$v^2 = 2.5048\,\Delta x - 0.0924$

Slope = 2.5048
$a = \text{slope} \div 2 = 2.5048 \div 2 = 1.2524\ m/s^2$

To calculate the expected acceleration for each incline, the angle of the ramp was determined using the triangle dimensions:

$\theta = \arcsin(\text{height} \div \text{hypotenuse})$

Procedure 1: $\theta = \arcsin(0.17 \div 1.22) = 7.97°$

Expected acceleration: $a = g \sin(\theta) = 9.8 \times \sin(7.97°) = 1.36\ m/s^2$

Procedure 2: $\theta = \arcsin(0.21 \div 1.22) = 9.88°$
Expected acceleration: $a = g \sin(\theta) = 9.8 \times \sin(9.88°) = 1.68\ m/s^2$

Conclusion

The experimental accelerations measured from the slopes of the v^2 vs Δx graphs were:

4 books: $a = 1.25\ m/s^2$

3 books: $a = 0.97\ m/s^2$

The expected accelerations calculated using $a = g \sin(\theta)$ were:

4 books: $a = 1.68\ m/s^2$

3 books: $a = 1.36\ m/s^2$

Percent errors:

4 books: $((1.68 - 1.25) \div 1.68) \times 100 \approx 25.6\%$

3 books: $((1.36 - 0.97) \div 1.36) \times 100 \approx 28.7\%$

The experimental values are slightly lower than expected. Likely sources of error include:

1. Friction between cart and track - This is the most likely dominant source. Friction will do negative work and reduce the cart's kinetic energy during each trial, producing smaller measured velocities and thus a smaller v^2 slope and smaller experimental a. This would make a too small, which is true in the results.

2. Air resistance on the cart - For these low speeds this is smaller than friction but still removes some kinetic energy, lowering v and causing underestimation of a.

3. Photogate alignment and sensor timing - If the photogate did not register the cart post at exactly the same position every trial or if the velocity measurement uses a finite measurement of the cart for instantaneous velocity, the recorded velocities would be less.

4. Non-negligible initial velocity or release technique variation - If the cart was sometimes given a small push or if the release point wasn't perfectly repeated, scatter would increase. However, this would likely increase scatter more than produce a consistent bias; our bias is towards a lower v, suggesting that the cart was mostly released closer to the photogate than intended.

5. Assumption of no rolling - Ideally, the cart would have no rolling friction and slip instead. Rotational motion would be negligible, so translational acceleration would approach g sin(θ). But because the cart is rolling down the ramp, some kinetic energy is lost to wheel rotation instead of pure translational motion.

Overall, the experiment successfully demonstrated that acceleration increases with ramp angle. The measured accelerations are reasonably close to the expected theoretical values, confirming the relationship $a = g \sin(\theta)$.