The Effects of Air Resistance on the Modern World

Carson Page

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Background .:. Top

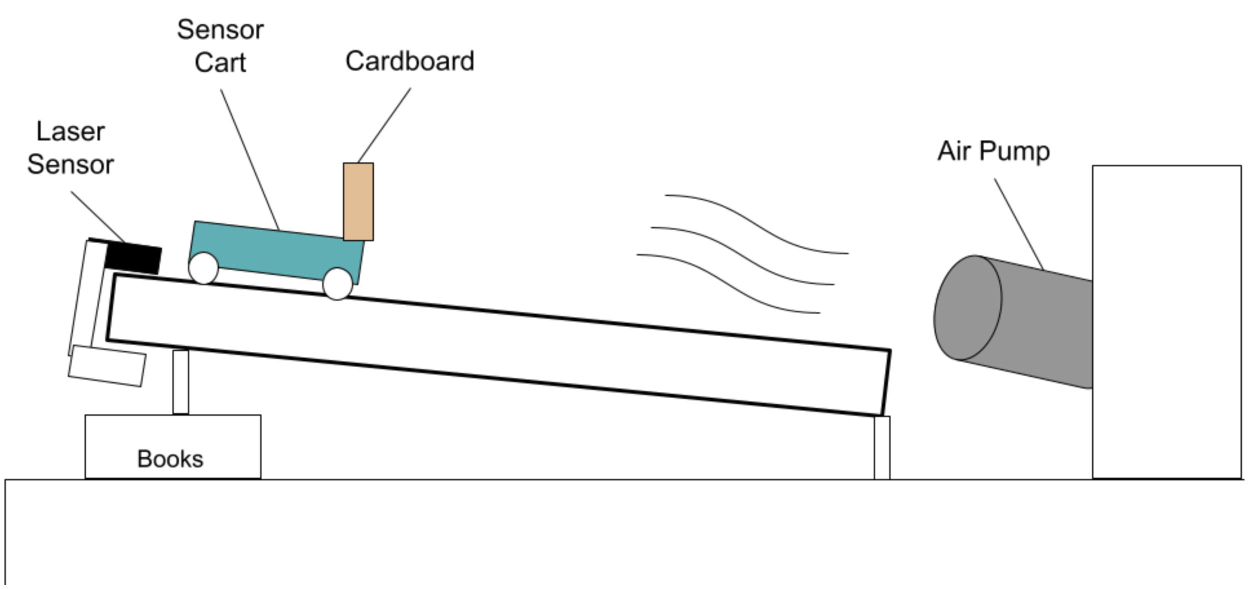
Air resistance is a challenge many engineers face in all aspects of travel. From space travel to air travel to even just an everyday car. Air resistance works by the amount of molecules in a fluid hitting an object in motion, those molecules slow down the object as it displaces those molecules. This is a problem engineers across the world face when building cars, planes, rockets, etc. A plane must limit air resistance as much as possible to gain enough speed to stay in the air. Cars must limit air resistance for better gas millage and less emissions. Most notably, NASA has been challenged by air resistance and friction on all its space flight missions. Calculating air resistance is crucial for determining the amount of power needed to escape, many factors go into such calculations as air resistance (drag), escape velocity, gravity, etc. Air resistance occurs more than just on vehicles though we experience it every day although not to such an extent. You have experienced air resistance if you have ever been in a strong storm while holding an umbrella and tried to walk through it, the wind pushes back on the umbrella as it catches the air molecules and holds you back.

This concept of air resistance is interesting because it shapes how engineers design and build the things that we use every day. The first documented research on air resistance came from Aristotle back in the 2nd century BC when he was studying the aerodynamics of an arrow. Still, aerodynamics never took off (pun intended) until 1726 when Isaac Newton developed his theory of air resistance, which later was verified at low flow speeds (Wikipedia). The formulas used in this investigation were not developed until 1738 when “Daniel Bernoulli described a fundamental relationship between pressure, velocity, and density, now termed Bernoulli's principle” (Wikipedia) but Bernoulli’s and Newton’s findings were derived into the drag equation used today in 1876 by Lord Rayleigh. It wasn’t until many years later that we had the first developed plane by the Wright brothers in 1903. Now aerospace engineers use this to make planes that may have a mass of upwards of 220 tons fly. It truly seems like a miracle but I aim to explain to some extent how it is done from a physics standpoint.

In this experiment, I will study the effects of surface area on the velocity of an object in motion to determine how air resistance may affect an object's speed. In this study, the surface area will vary as the velocity is recorded, my control variables are the angle of the track and the amount of airflow hitting the object. This study will not only show the effects of surface area on velocity but will also help to understand how lift is created and how air resistance can be limited. I believe that the velocity of the object will decrease gradually as the surface area increases and the drag is greater.

Method .:. Top

In this experiment, I used a “Vernier” sensor cart on a track with a motion encoder that uses a laser receiver to determine the distance from the cart. I also used a cardboard box that I cut down for a smaller surface area. To get more apparent data I used an air pump to blow more direct air against the cardboard. Under the track on one side, I put books to allow the cart to constantly accelerate using gravity.



Data Collection .:. Top

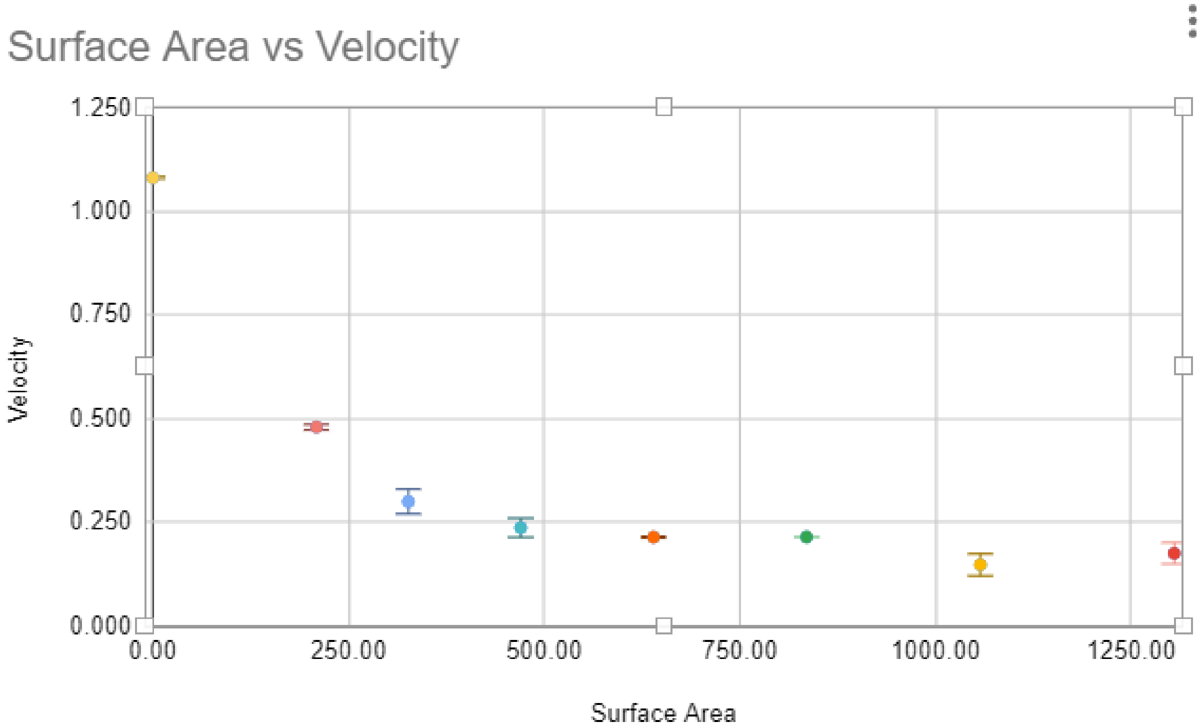
Data was collected by first measuring the cardboard to be 45x29 cm I then decided to get 10 variations, including a trial without the cardboard, I would cut each side by 4.5 cm and 2.9 cm respectively, I turned on the air pump and brought the cart to the top of the track I then ran a data collection program called Logger Pro at the same time as dropping the cart. Then, using Logger Pro, I found the max velocity during that trial. I ran 3 trials per variation cutting the board by 4.5 cm and 2.9 cm on the length and width respectively. I chose this amount of variations and trials because I noticed a need for more difference between trials and it did not seem necessary to get more data when data was so close together. I ended up only getting 8 variations as the cardboard got hard to cut and I didn't want to risk possibly compromising the data because of faulty cuts.

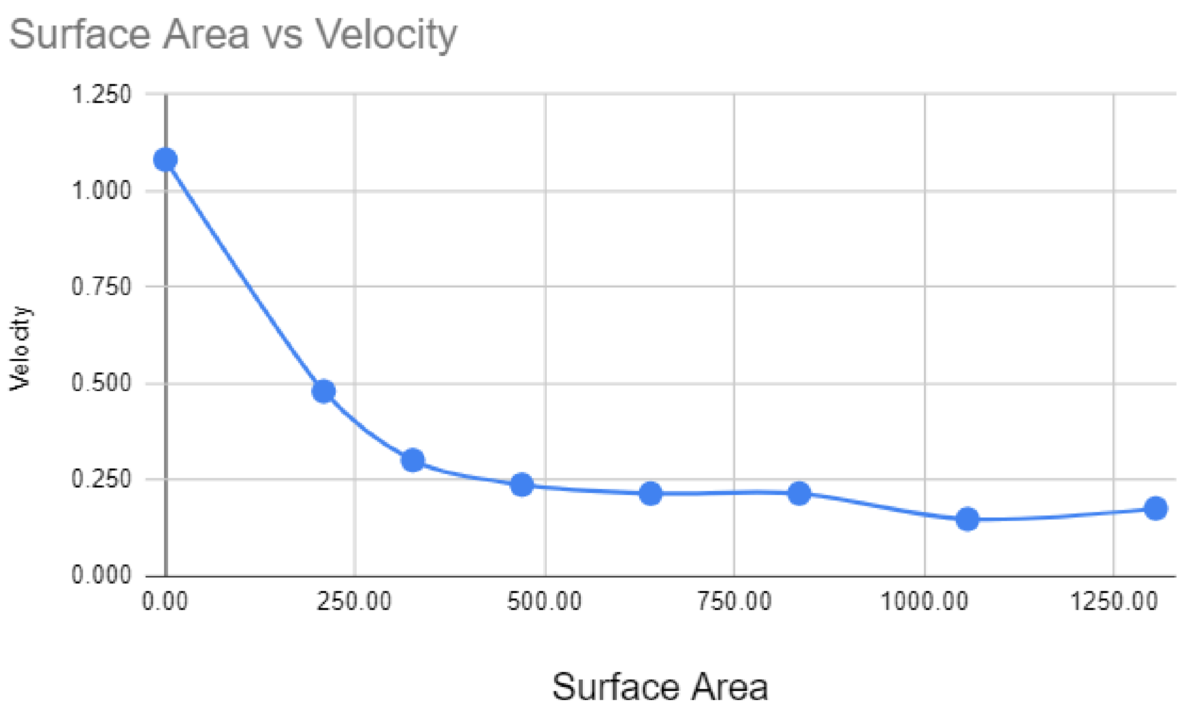
Raw Data .:. Data File .:. Top

Surface Area	Velocity				
+/- 0.05	V/ms^-1			m/s	m/s
A / cm^2	Trial 1	Trial 2	Trial 3	Average	Uncty
1305.00	0.207	0.156	0.167	0.177	0.0256
1057.05	0.149	0.175	0.122	0.149	0.0264
835.20	0.215	0.217	0.214	0.216	0.0014
639.45	0.217	0.213	0.216	0.215	0.0022
469.80	0.263	0.234	0.217	0.238	0.0231
326.25	0.337	0.290	0.277	0.301	0.0300
208.80	0.487	0.480	0.474	0.481	0.0064
0.00	1.083	1.078	1.084	1.082	0.0030

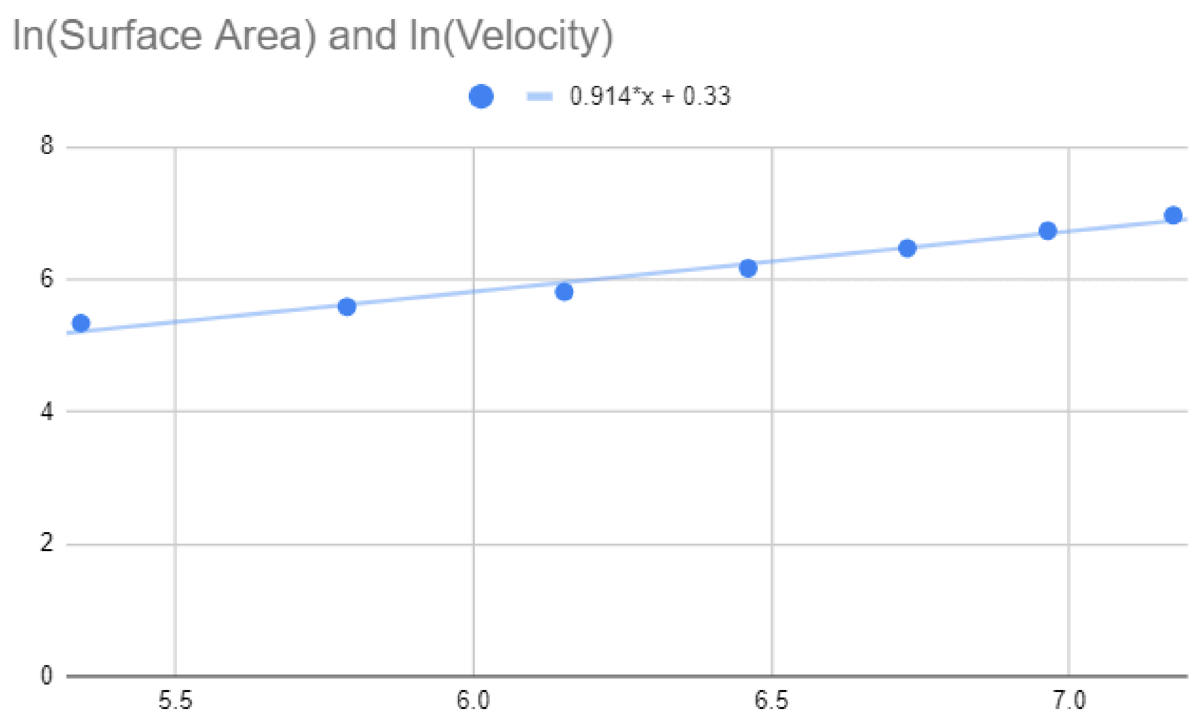
This sample of raw data shows the velocity at different surface areas in square cm as well as the possible uncertainty of that data. Logger Pro uses V=d/t to solve for velocity.

Graphed Data .:. [Top]

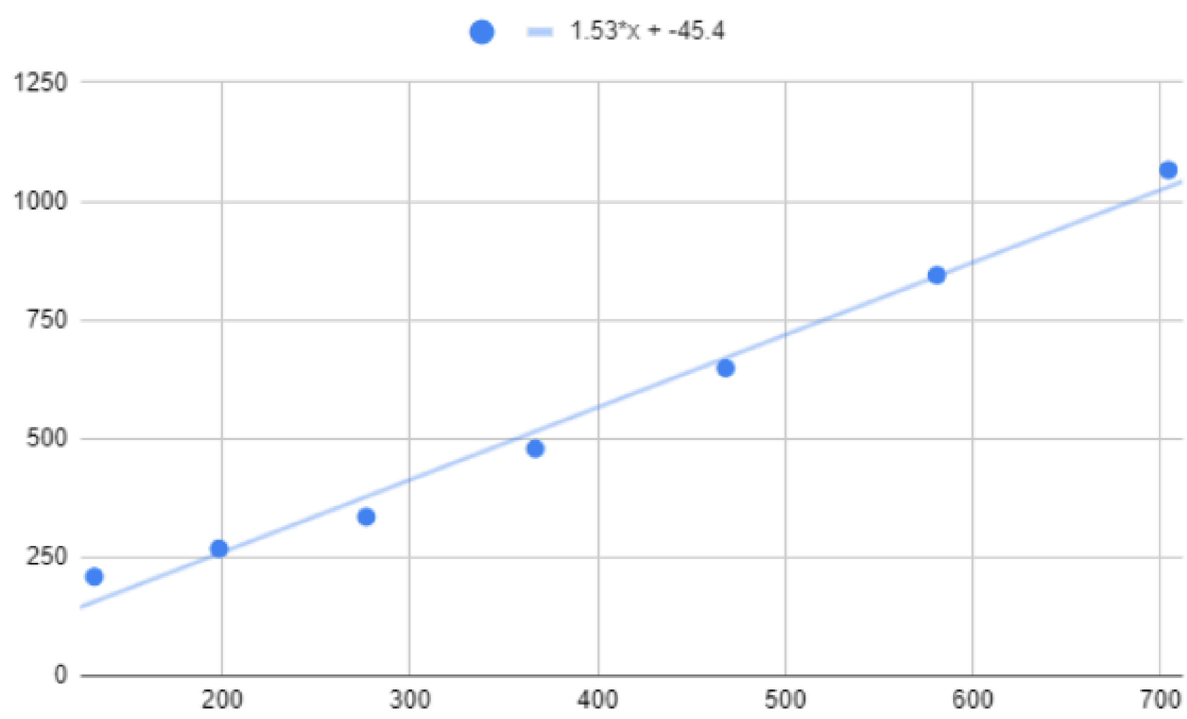




The first graph shows the averages of the trials with their uncertainty, while the second graph shows a better representation of the decrease in velocity. I then linearized the graph using the natural log of both axes. Which gave me this graph:



I took the gradient of that to then linearize the data so I can estimate other points on this graph as well this is the graph I got:



This graph has a slope of 1.53 which surprised me as I expected a slope of 2.

Conclusion .:. Top

This experiment further proves the drag equation which is:

$$F = \frac{1}{2}\rho v^2 CA$$

Where F is the force of drag and ρ is the density of the fluid in my case air, v is the velocity, C is the coefficient of drag and A is the surface area. I expected the slope of the linearized graph to be 2 because the power of the velocity is raised, but there are many reasons why this may not be true one of which may be human error maybe my cutting wasn't as precise so the measurements of the surface area were off, another reason may be because the cardboard was slightly tilted to maybe the force was not directly against the cart. Another reason may be that I didn't calculate the area of the cart itself which may have come into play, especially on the trials without the cardboard. I could have been more precise in my measurements and could've gotten more trials to possibly make the data more conclusive.

Related Links .:. Top

https://www.grc.nasa.gov/www/k-12/VirtualAero/BottleRocket/airplane/falling.html - NASA explanation of air resistance.

https://ngpd.nikon.com/en/glossary/air-resistance.html#:~:text=Air%20resistance%20is%20the%20force,object%20collides%20with%20air%20molecules. - Short explanation of air resistance on a molecular level.

https://resources.system-analysis.cadence.com/blog/msa2022-the-significance-of-the-air-resistance-formula-in-automobile-design - Importance of air resistance in engineering.

https://en.wikipedia.org/wiki/History_of_aerodynamics - History of air resistance research.

https://www.grc.nasa.gov/www/k-12/VirtualAero/BottleRocket/airplane/forces.html#:~:text=The%20air%20resists%20the%20motion,the%20%22stickiness%22%20of%20the%20air - NASA, forces on an airplane.

http://ismycomputeron.com/ - is it?