SASTA OLIPHANT SCIENCE AWARDS

South Australian Science Teachers Association

Highly Commended

Scientific Inquiry

Year 7-8

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How does weight affect aviation?

Introduction and Research

Legends such as the Persian Kay Kāvus and Archytas' flying dove brought light upon a whole new branch of physics. On November 21st, 1783, the first fully recorded aviator was created by the Montgolfier brothers. The vehicle was what we call today a hot-air balloon; vehicles like this are able to control their height by using the fact that hot air is less dense than cool air, creating a pressure imbalance. Although the Montgolfier brothers' invention was revolutionary, it had many limiting factors, notably its inability to use propulsion systems.

Hence, they needed to create a vehicle capable of propulsion. A vehicle like this is called a dirigible, these aviators use a gas that's less dense then air to move upwards, and then use engines on it to control it's direction by means of propulsion. All aircrafts similar to either one of these are known as lighter than air, aircrafts.

Nowadays, those aircraft aren't as common. Instead, we have aviators with fixed wings. These vehicles are known as heavier than air aircraft. Vehicles with fixed wings are able to move upwards using a force called lift; due to the shape of a plane's wings, the air above moves faster than the air below, creating an imbalance in pressure, moving the wing upwards, and generating lift. The aircraft creates thrust, moving the aircraft forward. You need thrust to operate a heavier-than-air aircraft, as the wings must have enough air going around them to continue generating lift. Otherwise, it'd stall. Like gravity is an opposing force for lift, drag is the opposing force for thrust, and drag is a resistive force that occurs whenever another object moves through a fluid at any speed.

Weights (Ratio of Aircraft weight to Simulated weight)

(Boeing 737 as our aircraft):(Simulated Weight)

The Boeing 737 is confirmed to have a maximum take-off weight of 80,000 kg. This includes the weight of the airplane and fuel which totals to 59 000 kg. Based of this we can conclude that the maximum payload of a Boeing 737 of approximately 21 000 kg.

Boeing 737	Simulated weight
59:	0
59:	5
59:	10
59:	15
59:	21

Planning and predicting

Based off Isaac Newton's 2nd law of gravity, "…an object with mass attracts another object with mass; the magnitude of the force is directly proportional to the masses of the two objects and inversely proportional to the square of the distance between the two objects." $F = G(m_1 * m_2)/R^2$ where F is the force of gravity. G is the gravitational constant. m_1 and m_2 are the two objects with mass that the equation is referring too, and R is the distance between those two masses. Gravity is measured in newtons.

Furthermore, lift is not affected by mass, meaning no matter how much more mass we do add the lift will stay the same. (The equation for lift $L = C_L * \frac{1}{2} * \rho * V^2 * A$, where L is the lift force. C_L is the coefficient of lift. ρ is the air density. V is the velocity of the aircraft relative to the to fluid it's moving through. A is the area of the wing. Additionally, to calculate the coefficient of lift you must use the equation $C_L = \frac{L}{r*\frac{V^2}{2}*A}$ where L is lift force, r is the fluid density, V is the velocity of the fluid relative to the body moving through it, A is the area of the wing. It is important to note that the coefficient of lift is usually determined experimentally.) Lift is measured in newtons.

Therefore, a larger mass will cause a stronger gravitational pull between the two, whilst the lift remains the same. Due to the ratio between the lift and gravity being altered this could cause the effectiveness of the flight to be limited.

For the most accurate results, you need to keep the thrust and drag the same.

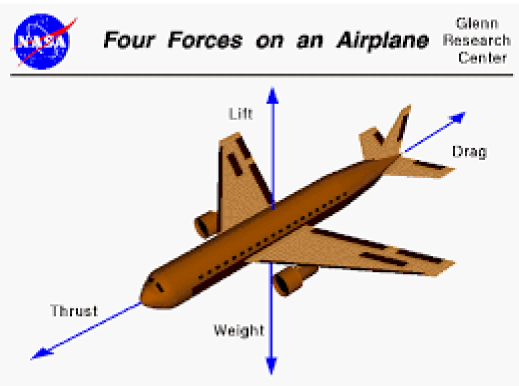
Thrust

Based on Isaac Newton's second law of gravity, "Force = Mass * Acceleration", due to the aircraft acting upon the air it means that it is defined as a mechanical force. Since thrust is a force, it is also a vector quantity as it has both a magnitude and direction. Based on these facts we can create an equation, $T = V\frac{dm}{dt}$, where T is thrust, V is velocity and dm is the change in mass and dt is the change in time.

Drag

Drag is the force opposing thrust. The equation for drag is $F_D = \frac{1}{2}\rho v^2 C_D A$, where $F_D$is the force of drag, ρ is air density, v means the velocity of the object relative to the air, C_D is the drag coefficient and A is the cross sectional area of the object.

We must keep account off all these variables to make sure our tests are accurate and not biased to a certain part of our test. For example, if we were to be measuring the distance depending on how much thrust the results could very easily be altered, as the more air moving around the wings the more lift we are generating.



What is the relationship between lift and gravity?

To sustain a particular altitude, the lift and gravity must be equal to each other. (If Gravity > Lift, then the plane will lose altitude, if Gravity = Lift it will maintain altitude and finally if Gravity < Lift you will gain altitude.)

To ensure for a fair test

In a fair test there are 3 types of variables. One that is changed (Independent), one that is measured (Dependent) and all the variables are kept the same. (Controlled)

The aim of this method is to isolate the independent and dependent variables to look at the effect on each other.

The independent variable was the simulated weight of the aircraft, in other terms the total weight. The dependent/measured variable was the take-off performance. To calculate the take-off performance, I decided to take the distance from the starting point to its final landing place.

Table 1:

Independent Variable	Simulated weight (The total weight.)
Dependent Variable	Distance
Controlled Variable	Aircraft weight (This is the weight of the aircraft its self, without any weights on it.)
	Thrust and drag
	Measuring device
	Aircraft body

Thrust is generated from a fan running on a high setting, this is to minimise any bias that may arise, this is because if I were to just throw it the thrust would be inconsistent and would mean that the results would be inaccurate. The drag is also connected to the thrust, this means that if one stays consistent the other will in turn be the same. As they are both reliant on the speed of the plane relative to the fluid it's moving through. (Which is usually notated as ρ in most equations requiring its use.)

Materials

Equally measured panels of cardboard boxes x3

Fan x1

Measuring Tape x1

Camera x1

Scissors x1

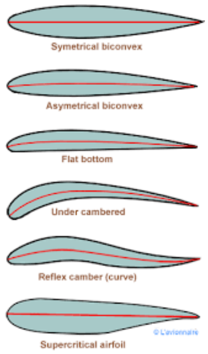
Sticky tape x1

Method

I decided that a glider (A hard winged aviator that has no means of thrust) would suit the expirement best. This is so we could calculate the pure distance without anything that would affect the results, that wasn't already a controlled variable or accounted for.

The glider is made out of a cardboard box, split into 3 different sections. The body, plane panels, and the stabilizer.

1. A glider was created, it was then checked out to make sure a number of components were correct.
    - The wing must be able to generate lift. This means that the wing must have a side profile similar to any of image below. The most and durable for most materials is flat bottom.



- The vertical and horizontal stabilizers must be of equal dimensions to ensure that the fluid will flow equally around all three of them.
- The nose must be weighed down otherwise it would tilt up and immediately lead to a stall of the aircraft.

2. Prepare a space for the expirement. Make sure it remains the same for the duration of all experiments.
3. The controlled variables were checked to ensure accuracy for the experiments.
4. A device was setup to record them. (To ensure that the plane didn't keep moving even whilst it was on the ground, and if it did, we would retest or measure an estimated location.)
5. The expirement began. All of them were measured with the same measuring tape.
6. The expirement was repeated.
7. The data was analyzed and the average of each of them were also assessed.

Results and Graphs

	59:0	59:5	59:10	59:15	59:21
Result 1	10.1	9.4	9.0	8.1	8.7
Result 2	10.5	9.0	8.6	9.1	7.3
Average	10.3	9.2	8.8	8.6	8.0

Risk Assessment

Possible Risks	Way to minimize/control the risk
Contact with sharp objects may in result in injuries	Exercise extreme precaution when in proximity of objects with sharp edges.
Contact with the planes at high speeds may cause injuries to people in the proximity	Warn people who may come into room about the expirement. Stand a good distance away from the plane or use something to block the path.
Cutting tape	Tape can either be cut using scissors or using a jagged end on a tape holder. Exercise precaution when cutting tape.

Analysis and Discussion

The purpose of the experiment was to figure out the effect that weight has on a plane in the air. The weight onboard the aeroplane increased while thrust and other elements remained the same. This was to isolate the variables of lift, gravity and drag.

The hypothesis suggested that the gravity-to-lift ratio was what would impact the results, but under more careful analysis, the glide ratio (Which is the ratio between lift and drag). This is because the aviator was a glider instead of a vehicle capable of propulsion, meaning that the ratio between lift and gravity didn't actually make a large difference. This is due to there not being enough fluid going around the wings to generate enough lift for the altitude to be consistent.

The data deemed a correlation between the distance an aviator travels and its weight. As the weight increased, the distance decreased.

This experiment doesn't incorporate the variable of thrust, this is as I had no motor or propellers to simulate thrust within my experiment. This is one of the reasons the experiment may be flawed in some ways, although it is good for the materials that I could use.

The main improvement that could've been made to the experiment was to create an even more aerodynamic vehicle; this could've been done by giving the nose of the vehicle a point, as the design that was used for the experiment didn't actually have one. This meant that the glider's drag was massive, which could've led to a less accurate experiment.

In summary, the experiment showed a positive correlation between the distance that an aviator travels and its weight. The larger the weight, the less distance there will be. The observed correlation did match the hypothesis, although the thought process was incorrect, as instead of the ratio between the lift and gravity, the ratio that actually impacted it was the gliding ratio (Lift to drag). The experiment displayed limitations in areas of itself, most importantly its inability to incorporate thrust into the experiment. While the experiment did have limitations, it still gave a very good insight into how the glide ratio worked and contributed to a broader understanding of aviation and physics.

Total word count:

1892 risk assessment and logbook are separate documents

Acknowledgement of help (And credits):

Irene Willcocks (Teacher)

Sister (Help with editing)

https://www.nasa.gov/

https://www.princeton.edu/~maelabs/hpt/mechanics/mecha_62.htm#:~:text=The%20lift%20coefficient%20is%20defined,symbols%20have%20the%20same%20meaning

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https://www.youtube.com/watch?v=A05Y-wCc73c

https://www.onverticality.com/blog/flying-throne-of-kay-kavus

Logbook:

1/5

Irene Willcocks (Teacher) got us to plan our project. I decided to do a science inquiry about how weight affects airplanes in motion.

8/5

We gave our registration forms to Irene Willcocks.

15/5

I began the research for my project. I learnt about the variables of lift, drag and thrust.

17/5

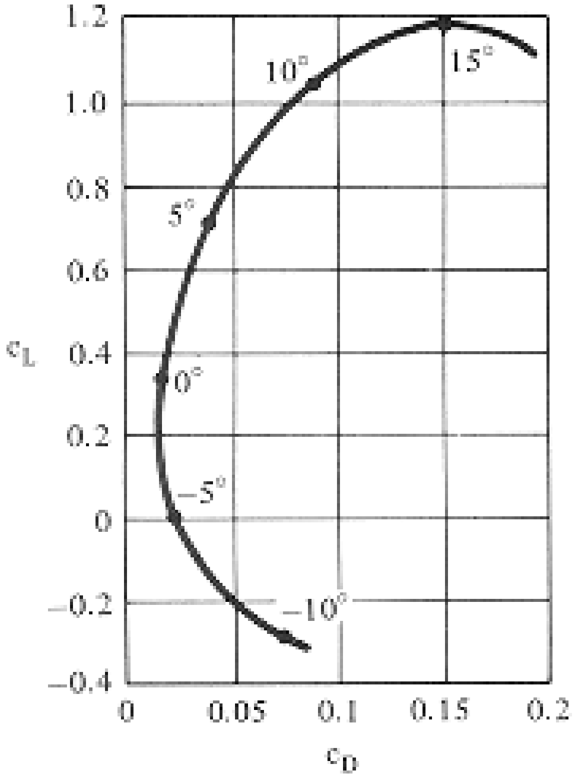
I began to write my introduction; I used research papers and the novel itself to research about Kay Kavus.

18/5

I learnt about Archytas's flying dove.

20/5-30/5

I learnt about various things during this time but I researched a lot about the forces of lift, drag and thrust.



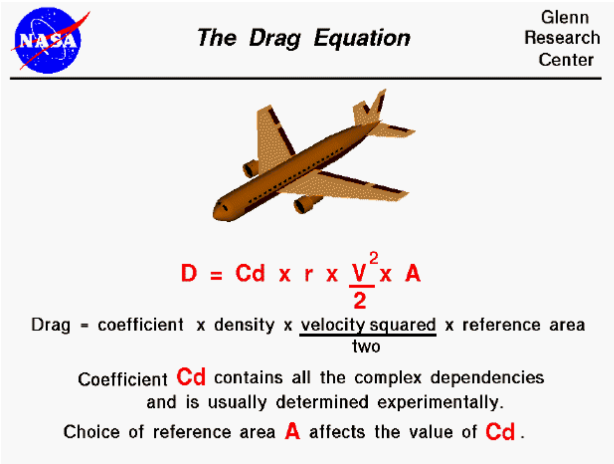
The Lift Equation

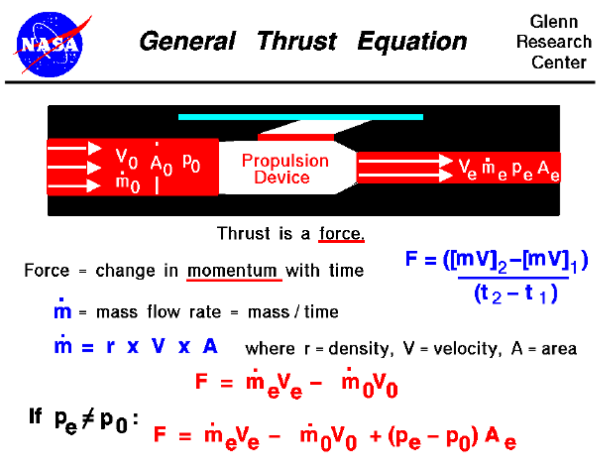
Glenn
Research
Center

$$L = Cl \times r \times \frac{V^2}{2} \times A$$

Lift = coefficient x density x $\frac{\text{velocity squared}}{\text{two}}$ x wing area

Coefficient **Cl** contains all the complex dependencies and is usually determined experimentally.





17/6

I created a glider similar to this one, it is supposed to use the elements of many other things. I even used the correct wing profile; this is to create a force of lift that opposes gravity.

Also note this wasn't my actual glider this was an image I found on the internet as my glider was broken during the testing stages.

20/6

I carried out the testing. With two tests for each noting it down and then taking the average for the final calculations. A fan was used to make sure the force that was used as the initial force for each of them was the same.

21/6

I wrote the discussion with feedback from my family members.

26/6

I submitted the document.