SASTA OLIPHANT SCIENCE AWARDS

SOUTH AUSTRALIAN SCIENCE TEACHERS ASSOCIATION

Highly Commended

Scientific Inquiry

Year 3-4

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Government of South Australia
Department for Education

SASTA South Australian Science Teachers Association

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1. Introduction

There are 4 forces that act on an aircraft. These are lift (L), weight (W), drag (D) and thrust (T). Lift is the force that keeps the aircraft in the air and is produced by the wings. Weight is the force acting downward produced by gravity. Drag is the frictional force acting opposite to the direction of motion. Thrust is the force produced by the engines acting in the direction of motion. All four forces control the motion of the aircraft from the time it takes off to the time it lands.

Figure 1: Forces on an aircraft [1]

Bernoulli's principle states that lift is generated by an aircraft's wing due to its shape [2]. Air flows faster over its upper surface and slower on the bottom surface. The faster moving air, creates lower pressure on the upper surface whilst the slower moving air creates a higher pressure underneath the wing. This high pressure pushes up on the wing creating lift. An aircraft can control lift by adjusting the wings angle of attack. As the angle of attack increases, the wing is said to stall, thereby producing no more lift.

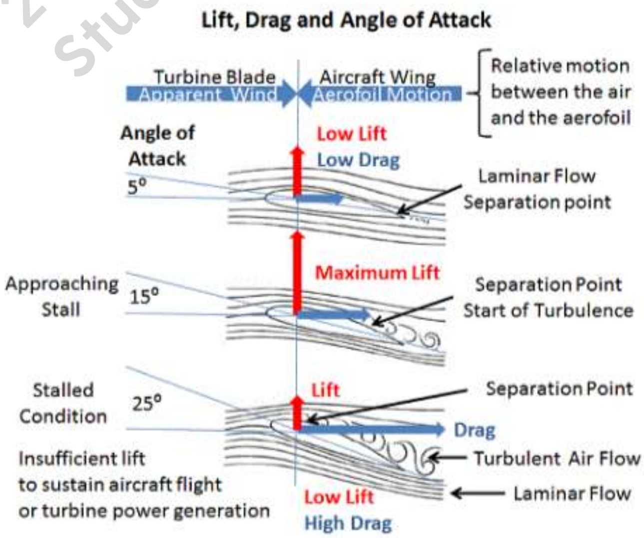


Figure 2: Lift on an aircraft wing [3]

It is important to study the air flow over a wing in order to understand how it behaves in various conditions. This information can then be used to design wings to improve the efficiency of the aircraft.

2. Apparatus

2.1 Building the wing

The following material was used to build the wing.

- Polystyrene
- Hot wire cutter
- Cardboard
- Paper glue
- Tape measure
- Sand paper (Fine)

2.1.1 Method

The simplest wing shape I found during my research was that of a NACA 0012 airfoil. Repeat the following steps to construct the wing.

- Print two copies of the wing profile and stick onto two pieces of cardboard

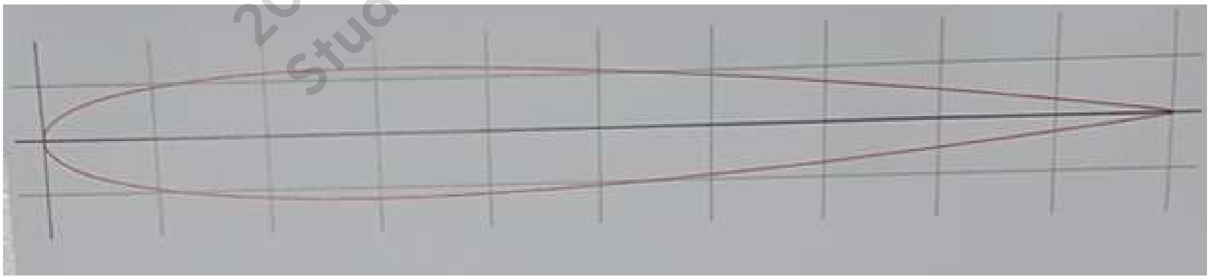


Figure 3: NACA 0012 airfoil

- Cut out the two shapes and use this as a template for the wing

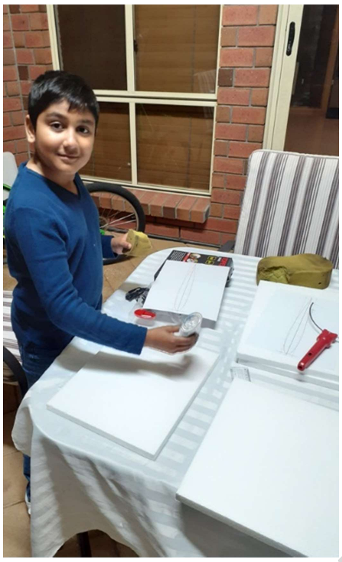


Figure 4: Creating the wing template

- Stick the cardboard templates on opposite sides of the polystyrene block

Figure 5: Polystyrene hot wire cutting tool

- Once the glue is completely dry, use the hot wire tool to cut the shape of the wing. Also, insert a wooden rod at the centre of the wing to assist in the holding of the wing during testing

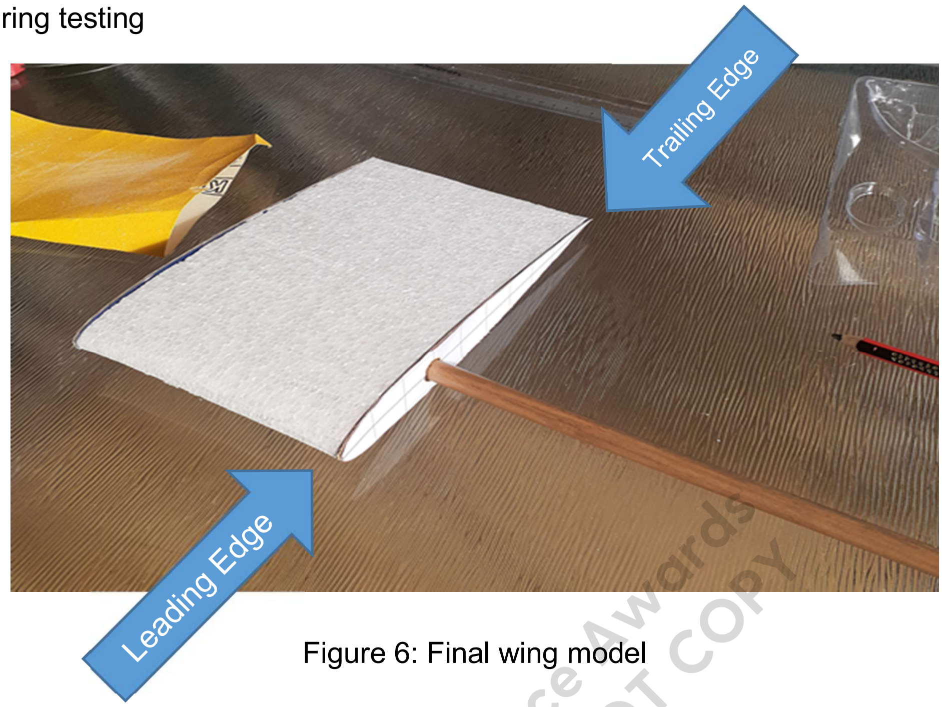


Figure 6: Final wing model

2.2 Setting up the test station

The following items are required to set up the testing station:

- The model wing
- Cotton tied to the end of a wooden dowel
- 360° protractor
- Ruler
- White board (With markers)
- Electric hairdryer

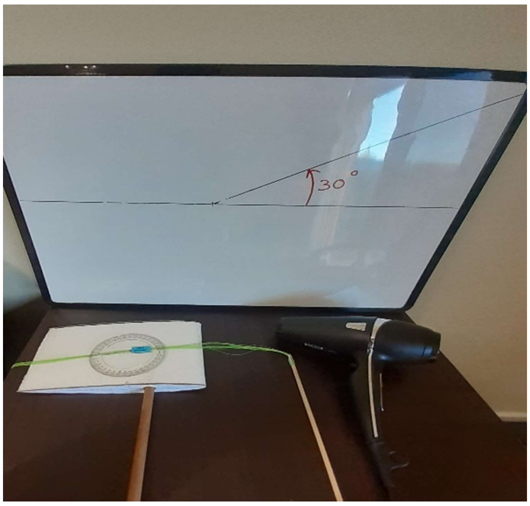


Figure 7: Wing test station

3. Results

Using the white board, protractor and ruler, align the wing at an angle of attack of 0°. Turn on the hair dryer and watch the movement of the cotton over the wing.

Figure 8: Air flow over a wing at angle of attack at 0°

Now, mark on the white board an angle of attack of 15°. Align the wing at 15° and watch the airflow.

Figure 9: Air flow over a wing at angle of attack at 15°

Finally, mark an angle of attack of 30° on the white board. Align the wing at 30° and note the airflow.

Figure 10: Air flow over a wing at angle of attack at 30°

4. Discussion

As shown in figure 8, when the wing is set at an angle of attack of 0° the air flows smoothly over the top surface of the wing. This is called laminar flow [3]. The air is seen to separate at a further distance from the leading edge of the wing. The wing will generate a low amount of lift as the air flows smoothly over its surface. Towards the trailing edge of the wing the airflow is seen to be circular. This circular motion of air is known as vortex flow.

Figure 9 shows the wing at an increased angle of attack of 15°. The air separates from the wing at a closer distance to the leading edge. As it separates, the flow changes from laminar to turbulent. This turbulent flow creates a circular vortex after the separation point and pushes the trailing edge down [2]. This creates lift as the leading edge is forced upward by the higher pressure generated under the wing due to the slower moving air. A larger vortex is created after the trailing edge of the wing.

When the angle of attack is increased to 30° the separation point of the air is even closer to the leading edge. This creates a much stronger vortex but no more lift can be generated as the separation point occurs at the point at which lift is produced. At this point the wing is said to stall. The vortex after the trailing edge of the wing is even larger.

5. Conclusion

- The lift force on an aircraft is produced by its wings.
- A model of a wing was crated based on a NACA 0012 airfoil profile.
- The wing was tested at 3 different angles of attack.
- At an angle of attack of 0° the air flows smoothly over the top surface of the wing. A low amount of lift is produced.
- At an angle of attack of 15°, the air is seen to separate from the wing as it passes over it. As the air separates, a circular vortex is created. This pushes the trailing edge down hence creating lift as the leading edge is forced upward by the higher pressure generated under the wing due to the slower moving air.
- As we further increase the angle of attack to 30°, the wing is seen to stall. This means no more lift can be generated.
- By studying air flow over a wing, we can design and build wings that are more efficient and improve the overall performance of an aircraft.

6. Recommendation

During testing of the wing, the vortex created at the trailing edge grew larger as the angle of attack increased. It would be interesting to investigate the behaviour of the vortex and determine what effect this has on the overall performance of the wing.

7. References

[1] https://howthingsfly.si.edu/media/four-forces-act-airplane

[2]
https://www.sciencekids.co.nz/lessonplans/flight/flightintroduction.html#:~:text=Bernoulli%E2%80%99s%20principle%20helps%20explain%20that%20an%20aircraft%20can,while%20slow%20moving%20air%20equals%20high%20air%20pressure.

[3] http://article.sapub.org/10.5923.j.jmea.20160604.03.html

8. Acknowledgement

My dad supervised the use of the hot wire cutter when building the wing.

Thank you mum for allowing me to use your hairdryer to test the wing.

9. Logbook

9.1 My Research Journey

1) June 16th – Collected SASTA topics from Mrs Howie at St Andrews School.

2) June 17th – Decided to do a Scientific Inquiry project.

3) June 18th to June 26th – Researched the topic of how an aircraft flies. I have put together a presentation shown in Appendix 1 to document my research. During my research I discovered the wing is the most important component of the aircraft responsible for getting the aircraft off the ground.

4) June 27th to June 30th – I researched building my own model wing.

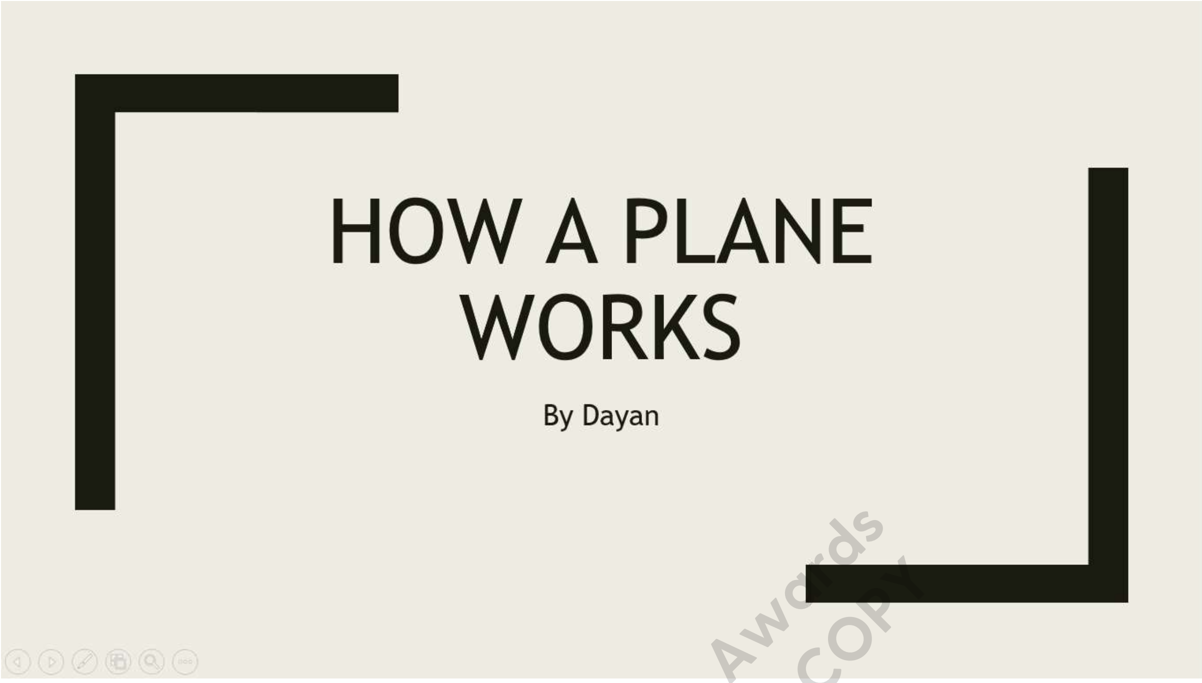
5) July 1st to July 3rd – Bought all the materials required to build the wing.

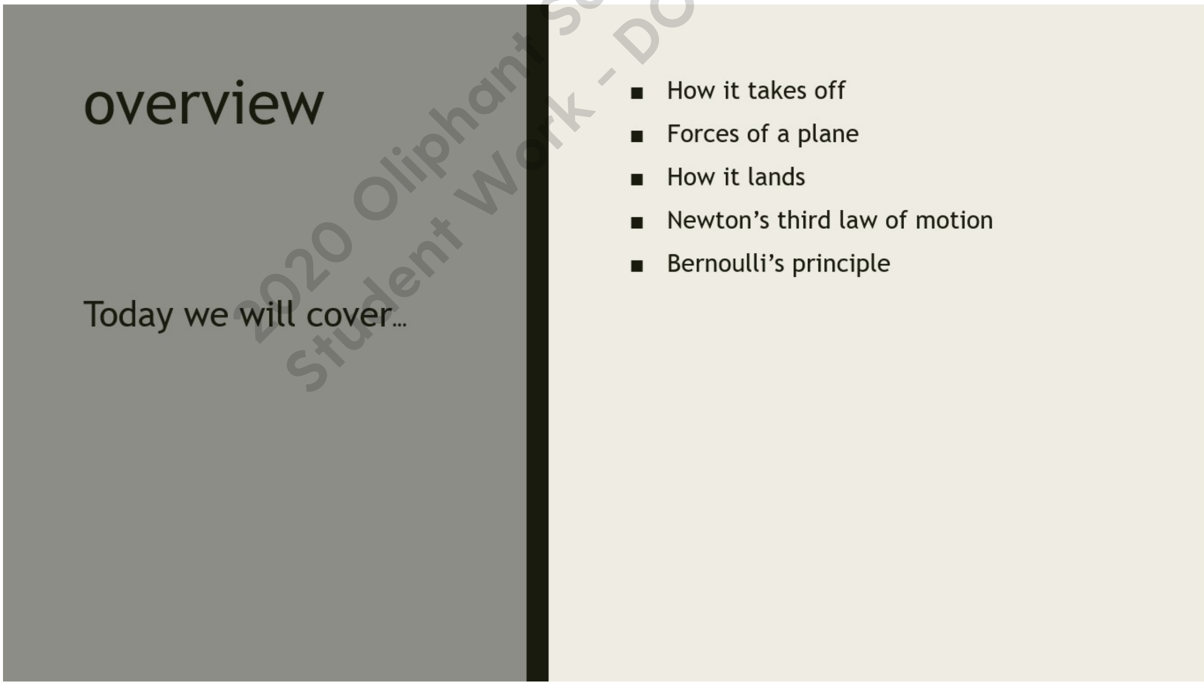
6) July 4th to July 6th – Built the wing.

7) 7th July 10th July – Testing the wing.

8) 11th July – 20th July – Putting my research report together.

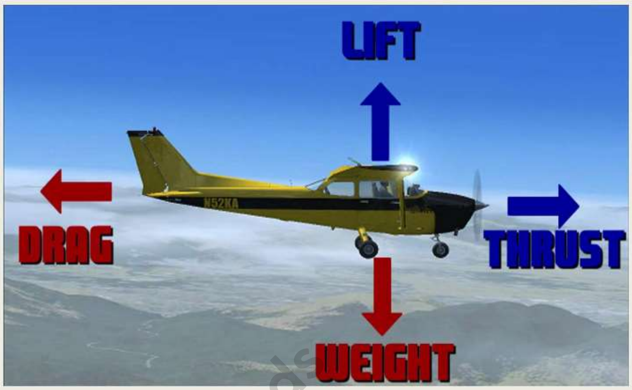
Appendix 1: How a plane works





Forces of a plane.

- On a plane there are 4 different types of forces they are …



Meanings

- Lift is the force the keeps the plane in the air.
- Weight is the force that pulls the plane down (gravity)
- Thrust is generated by turbines within the engine.
- Drag is the friction force that acts opposite to the direction of motion

How it takes of

- A plane takes of when it reaches enough speed and it can reach the escape velocity (lift).

How it lands

- A plane lands when the flaps on the wing are active causing it to go down.

Newton's third law

- When one body exerts a force on a second body, the second body simultaneously exerts a force equal in magnitude and opposite in direction on the first body.

(in other words)

- If a person is in motion and touches someone else it will cause a chain reaction.

Bernoulli's principle

- **increase in the speed of moving air or a flowing fluid is accompanied by a decrease in the air or fluid's pressure.**

(Newton's third law is similar to Bernoulli's principle)

It's just in Bernoulli's words.