



Royal Academy
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DRONES: FRIEND OR FOE?

Optimal propeller

This resource is designed to be a practical way to explore the physics of lift.

THE OPTIMAL PROPELLER

Quadcopter during takeoff



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Introduction

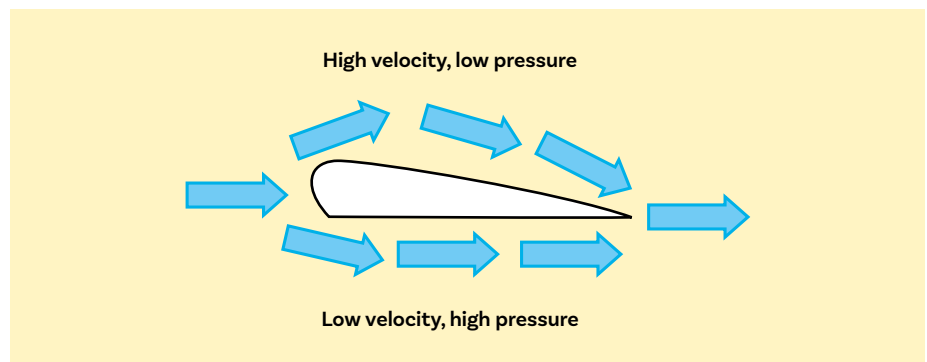
One of the challenges for the designers of unmanned aerial vehicles (UAV), such as quadcopters, is to design a system for getting the vehicle off the ground and remaining airborne.

To become airborne, the upwards force (lift) on the drone must be greater than the downwards force (weight). Lift is produced when air flows over the propeller blades. Due to the shape of the propeller, the air travels faster over the top of the blade than below the blade. This means the pressure above the blade is lower than below the blade, which causes suction above the blade that moves the drone up.



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Sycamore seeds:
the natural propeller



Propellers in nature

Propellers are used in nature, by trees, for example, to ensure safe dispersal of seeds. Samaras, or single-seeded winged fruit, such as sycamore seeds, use the wind as their dispersal mechanism. The shape of the samara enables the wind to carry the seed further away than regular seeds from the parent tree.

The challenge

Your challenge is to design, make and test a propeller that will provide the maximum amount of lift.

Activity 1 – Making a propeller

First you must make the propeller to test. Figure 1 provides some suggestions for the materials and components you might use to make your prototype propeller.

- A 210 mm long plastic straw (4mm diameter)
- B Connector
- C Corrugated plastic (100 mm x 20 mm x 3 mm)
- D Card (100 mm x 20 mm)
- E Adhesive tape

Figures 2–5 show how you might join the materials and components shown in Figure 1 to make a prototype propeller.

To make a propeller from corrugated plastic follow figures 2 and 3.
To make a card propeller follow figures 4 and 5

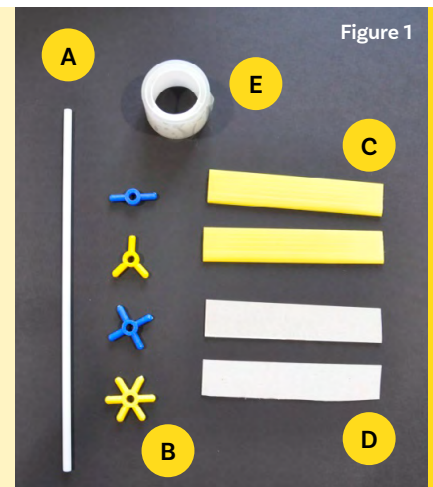


Figure 1

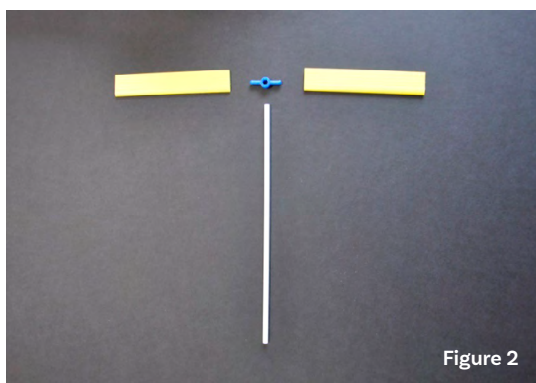


Figure 2

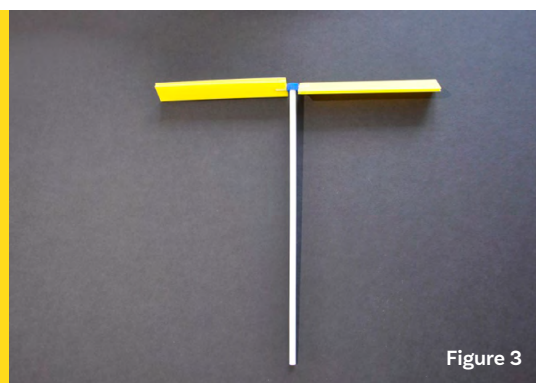


Figure 3

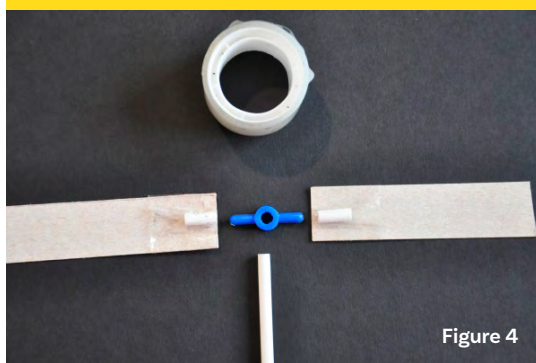


Figure 4

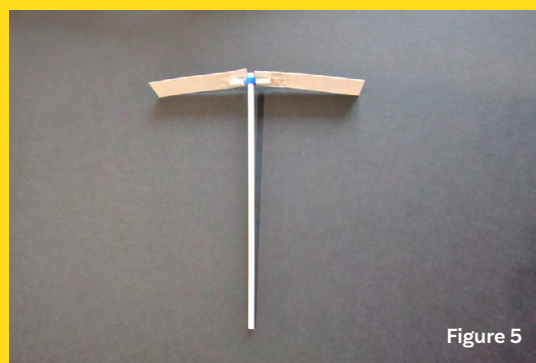


Figure 5

Figures 2–5

Figure 6 shows a method for launching your prototype propeller.

- Place the propeller between your palms
- Rub your palms back and forth to spin the propeller
- Let go of the propeller as it spins to see if it will lift off

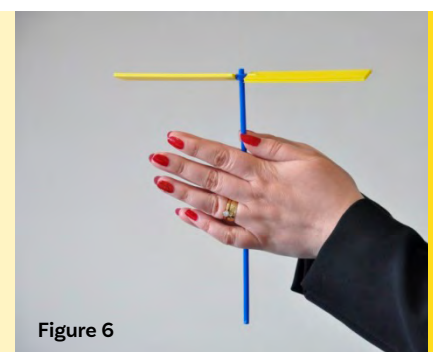


Figure 6

Activity 2 – Testing your propeller

See what happens when you experiment with changing the angle of the propeller blades.

- How does the angle affect the maximum height the propeller reaches?
- How does the angle affect how far the propeller travels?

Angle of attack

The angle of attack is the angle of a wing in relation to a horizontal reference line.

A wing's critical angle of attack produces the maximum amount of lift.

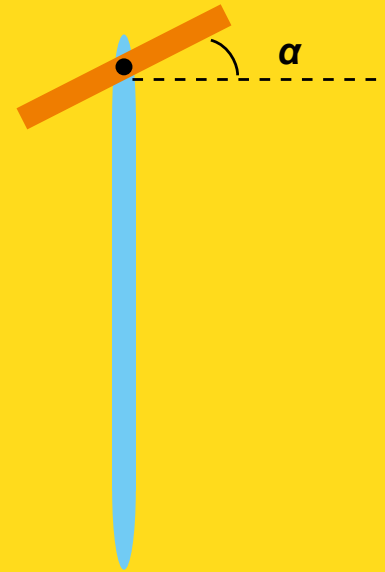
Can you identify the critical angle of attack for your propeller design's blades?

Modifying your design

Try some of the following modifications:

- Decreasing the length of the propeller blades
- Increasing the number of propeller blades
- Decreasing the width of the propeller blades
- Changing the shape of the propeller blades
- Changing the material from which the propeller blades are made

What affect do they have on the height and distance travelled?



Side view of propeller blade

Activity 3 – Conclusion

Now you have designed, made, tested and modified your propeller, try to answer the big question:

What makes a good propeller? Does your conclusion match the conclusions of others in the group?

Stretch and challenge 1

Launching the propeller with your hands means you will apply a different force each time, no matter how careful you are.

This introduces error to your results and means the results are not repeatable.

Can you design a launch devise to ensure your results are repeatable and reproducible?

Working scientifically keywords

Repeatable – Results are repeatable if you get the same results each time you repeat the investigation using the same method and equipment.

Reproducible – Results are reproducible if the same results are obtained when the investigation is repeated using different equipment or by another person.



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Stretch and challenge 2

Investigate what happens when you add weights to the propeller. You could do this by attaching paperclips.

Plot a graph of weight of propeller against time of flight.

What conclusions can you draw from your results?

NOTES FOR TEACHERS

The perfect propeller design depends very much on the engine size and aircraft it is designed to lift.

Generally, a larger surface area produces a greater lift. So increasing the number of blades or increasing the width of the blades will increase the lift. However, when the blades become too close together it interferes with the air flow on the nearby blades so this no longer applies.

Activity 2

For the 'modifying your design' part of the activity, you might like to split your class into teams to test different aspects of the design, and share the results with the rest of the class.

Activity 3

For this activity, ask each team from the previous activity to create a presentation answering the question: *What makes a good propeller?*

This could be a good opportunity for peer assessment of presentations skills and engineering content.

Additional ideas to extend the activity

You could ask the students to look at one or more of the variables quantitatively and plot a graph of their results. For the graph, you could measure either time of flight or top height as the dependent variable, or ask the students to decide.



Quadcopter propeller
blade



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Together we're working to tackle the greatest challenges of our age.

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We're developing skills for the future by identifying the challenges of an ever-changing world and developing the skills and approaches we need to build a resilient and diverse engineering profession.

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