Measuring Forces On a Wing – KS3 & KS4 Science

- Teacher and technician notes

Ages 11-16 via 2 experiments with a common core & different extension tasks

Specification References

KS3 National Curriculum
- opposing forces and equilibrium
- pressure measured by ratio of force over area
- using force arrows in diagrams, adding forces in one dimension, balanced and unbalanced forces
- moment as the turning effect of a force
- non-contact forces

KS4 National Curriculum
- weight and gravitational field strength
- forces as vectors

GCSE Edexcel
- 2.2 Explain that a vector quantity has both magnitude (size) and a specific direction
- 2.13 Recall that the acceleration, g, in free fall is 10 m/s^2 and be able to estimate the magnitudes of everyday accelerations
- 2.14 Recall Newton's first law and use it in the following situations: a where the resultant force on a body is zero, i.e. the body is moving at a constant velocity or is at rest b where the resultant force is not zero, i.e. the speed and/or direction of the body change(s) 1a, 1d 2a 3a, 3c, 3d 2.15
- 2.16 Define weight, recall and use the equation: weight (newton, N) = mass (kilogram, kg) × gravitational field strength (newton per kilogram, N/kg) $W = m \times g$
- 2.17 Describe how weight is measured
- 2.18 Describe the relationship between the weight of a body and the gravitational field strength

GCSE OCR
- P2.2c represent such forces as vectors drawing free body force diagrams to demonstrate understanding of forces acting as vectors
- P2.2h describe, using free body diagrams, examples of the special case where forces balance to produce a resultant force of zero (qualitative only)
- PM2.3iii recall and apply: gravity force (N) = mass (kg) x gravitational field strength, g (N/kg)
- P2.3o use the relationship between the force, the pressure and the area in contact

GCSE AQA
- 4.5.1.2 Contact and non-contact forces. Force is a vector quantity. Students should be able to describe the interaction between pairs of objects which produce a force on each object. The forces to be represented as vectors.
- 4.5.1.3 Gravity Content Key. Weight is the force acting on an object due to gravity. The weight of an object can be calculated using the equation: weight = mass × gravity
- 4.5.1.4 Resultant forces. A number of forces acting on an object may be replaced by a single force that has the same effect as all the original forces acting together. Use vector diagrams to illustrate resolution of forces, equilibrium situations and determine the resultant of two forces.

Aims KS3

1. Practically measure force of lift on a wing
2. Explain how forces can oppose to a state of equilibrium
3. Use the understanding moments to balance an equilibrium
4. Introduce students and teachers to the sport of gliding

Aims KS4

1. Practically measure force of lift on a wing
2. Explain using vectors that when a wing is in steady state the forces on the wing are balanced
3. Introduce students and teachers to the sport of gliding

Technician notes

Equipment and materials required

The following will be required for each student, or each group of students.

- Card 15cm x 21cm (envelope folders is a suitable thickness)
- Sellotape
- Copper wire 1.5 – 2mm diameter – 37cm length
- Clamp stand
- Permanent marker
- Bose and rod
- Blu tack
- Hair drier
- Balance (accurate to 0.1g)

Building the Wing Balance

This can be done by students if time permits alternatively these can be prepared before hand

1. Wrap a 37cm length piece of copper wire once around a metal rod
2. The wrap should be in the centre of the wire. (Figure 1)
3. Repeat the steps 1 & 2 to make 2 wires

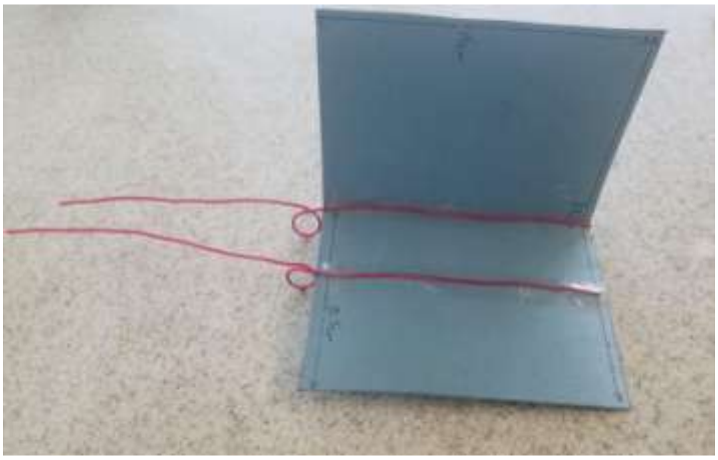
Figure 1

4. Cut a piece of card 15cm x 21 cm
5. Fold 10.5cm down the longest side (Figure 2)

Figure 2

6. Sellotape one of the pieces of wire down the length of the fold
7. Sellotape the second piece of wire about 3cm parallel to the first wire (Figure 3)

Figure 3



8. Form the wing shape by sellotaping the 2 short edges but do not Sellotape edge to edge. (Figure 4)

Figure 4

9. Cut another piece of card approximately 15cm x 4cm and Sellotape it to the 2 exposed wires, forming a "platform"
10. Draw a large cross with a permanent marker on the "platform" 8.5cm from the centre coil. This is the point where the wing will be balanced by the students (Figure 5)

Figure 5

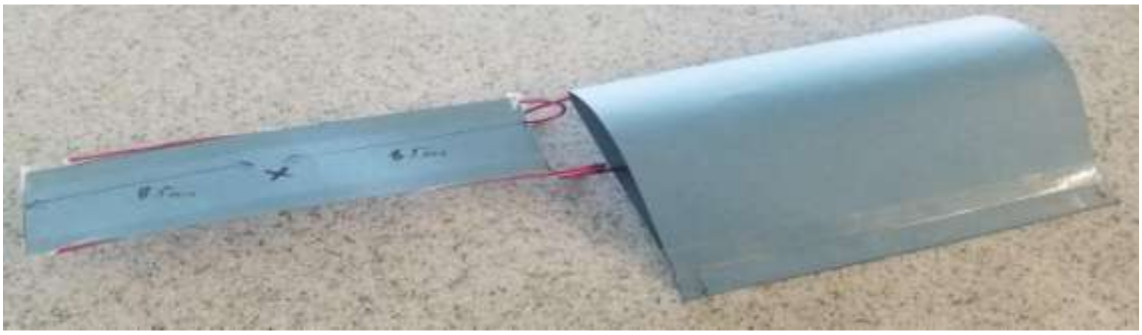


Figure 6

11. This can now be mounted on a clamped metal rod so the wing can pivot around the centre loops of copper (Figure 6). The wing should be unbalanced with the platform pointing upwards
12. Add enough Blu Tac to anywhere on the **underside** of the platform so the wing is **still not balanced** (platform is higher than the wing – Figure 7), but **becomes** balanced (platform is level with the wing) when a hair drier is blown across the leading edge of the wing (Figure 8)

Figure 7

Figure 8

13. The wing balance is now prepared for classroom use

Teacher notes

- If time is limited the wing balances can be prepared in advance.
- This activity aims to help students to see and explain the link between lift and air passing around a wing profile.
- Students should be able to identify 2 forces present: Weight from the wing and lift generated from air passing over the wing.
- Some students may need help understanding the weight of the Blu Tac needed to balance the wing (without the hair dryer) is the same as the lift generated with the hair dryer.
- Students should be reminded to only weigh the Blu Tac they have added to balance the wing and not the Blu Tac attached to the underside of the platform
- When the students are weighing the Blu Tac the mass in grams will need to be converted to kg.

Practical tips

- Hold the hair dryer level with, and blowing directly at, the leading edge of the wing. Try and avoid blowing the wing from below as the lift will not be generated by air passing over the wing.
- Don't hold the hair dryer too close the airflow is more turbulent and this will result in less lift
- If the wing fails to lift add a little more Blu Tac to the balance side. It is important however, when no air is being blown over the wing that the balance side is higher than the wing side
- If the wing lifts too high remove a little Blu Tac from the balance side.

Extension Activities

- **KS3 Extension activities** explore how to increase the lift produced:
    - How would you increase the lift being produced by the wing?
        - Answers include changing the angle of attack of the wing, increasing the airspeed/hairdryer speed setting / changing the wing form
    - Moments can be investigated by reducing the mass of the Blu Tac and changing its distance from the pivot point.
    - How will changing the shape of the wing change the lift it produces?
        - See comment in wing design box below
- **KS4 Extension activities** explore how lift is used to control an aircraft as well keeping it airborne:
    - How much lift is needed to keep a 500kg glider airborne
        - Answer should recognise the equilibrium state of lift = weight
    - What happens if lift is not equal on each wing
        - Glider will roll and once banked will turn. Elicit responses as to how this is achieved – viz using ailerons. Unlike a boat, the rudder doesn't turn an aircraft, it only yaws it sideways to the airflow. Instead banking provides the force towards the centre to make it turn.
    - How does the elevator control the pitch of the glider?
        - Elevator down = more lift = tail up = nose down, and vice versa
    - How will changing the shape of the wing change the lift it produces?

Teacher notes on wing design:

In general a 'fatter' wing ie with a deeper section top-to-bottom will produce more lift at a given airspeed. When an aileron is lowered, the wing effectively becomes 'fatter' and generates more lift - and the converse applies on the opposite wing where the aileron rises - so the glider banks and so turns. Flying faster increases the airflow and so also produces more lift, however as more lift is produced so is more drag - the aerodynamic lift equivalent of friction. Thus the wing's performance degrades and to minimise this, flaps can be used to change the shape of the wing so that optimum wing shape can be achieved over a wider speed range. Typically in powered aircraft this is for take-off and landing, and for gliders there are also settings for thermalling (climbing in rising air) when the glider benefits from flying more slowly in the core of the thermal, and for high speed cruising flight between thermals.

Fun fact – did you know that the upturned tips on the end of the Airbus and other commercial jets were originally developed on gliders? Improving the glide performance of a glider translates into improving the fuel efficiency of an airliner.

Find out more about gliding at the addresses below, all forms of aviation at airleague.co.uk and the huge range of careers at stem.caa.co.uk/careers-in-aviation-and-aerospace

womengliding.co.uk
gliding.co.uk
members.gliding.co.uk/junior-gliding