STEM ACTIVITY 1
TEACHER NOTES

AIRCRAFT DESIGN

RAF 100

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EQUIPMENT REQUIRED PER STUDENT:

- Copy of STEM student instructions
- Glider Sticker Template printed onto A4 sticker sheet
- Depron foam sheet (A4, 3 mm thickness)
- Sticky tape or masking tape
- Scissors
- Blu-tack
- Penny
- String (approx. 30 cm length)
- Copy of STEM extension sheet (optional)

PREPARATION REQUIRED

You may need to download the accompanying video: Early Aircraft. Depron foam is usually sold in model shops or online in sheets larger than A4; you will need to cut up the sheets before the activity. Ensure that students have enough space to test fly their gliders over a distance of at least 4m.

CURRICULUM LINK: CENTRE OF MASS, MOMENTS

STEM ACTIVITY: BALANCED FLIGHT

In this activity, students build a glider to explore how the position of an aircraft's centre of mass affects its balance.

Introduce the activity by playing the accompanying video: *Early Aircraft*. If students are unfamiliar with the concept of **centre of mass**, **C_M**, introduce it as the point at which an object balances (see figure 1).

Students should follow the STEM activity instructions to build a glider. For ease and speed of construction, the template provided is for a single-winged (monoplane) design. Emphasise that although most of the aircraft used in the First World War were biplanes, the same principles of balancing forces apply to their glider: for steady flight the downward force of gravity must be balanced by an upward lift force created by the wings.

Once they have built their glider students should determine the position of its centre of mass and find that the C_M is approximately at the centre of the fuselage. When they test-fly their glider, it will be unstable, pitching upwards and stalling.

Moving the position of the C_M will balance the glider. Students should attach a penny to the nose of the glider and carry out further test-flights, adjusting the C_M by moving the penny and/or adding blu-tack. Balancing the glider and optimising the throwing technique will take a few attempts, but ultimately students should be able to achieve horizontal flight over a metre or so. They should conclude that, for a balanced flight, C_M needs to be towards the front of the glider.

BIPLANES

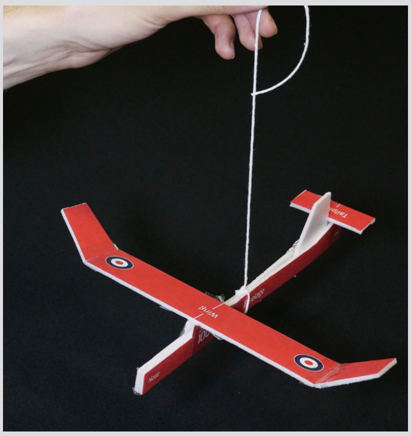
Biplane configurations were preferred by early aircraft designers because the wood and fabric wings available at the time were prone to bending and snapping. Using two wings spread the force over the greater area, reducing the stress on each wing.

FIGURE 1:
FINDING THE CENTRE OF MASS

The glider's C_M can be found by finding the point at which it balances.

Left: A glider suspended by string at its C_M.

Right: A glider (with penny added) balanced on two fingers.



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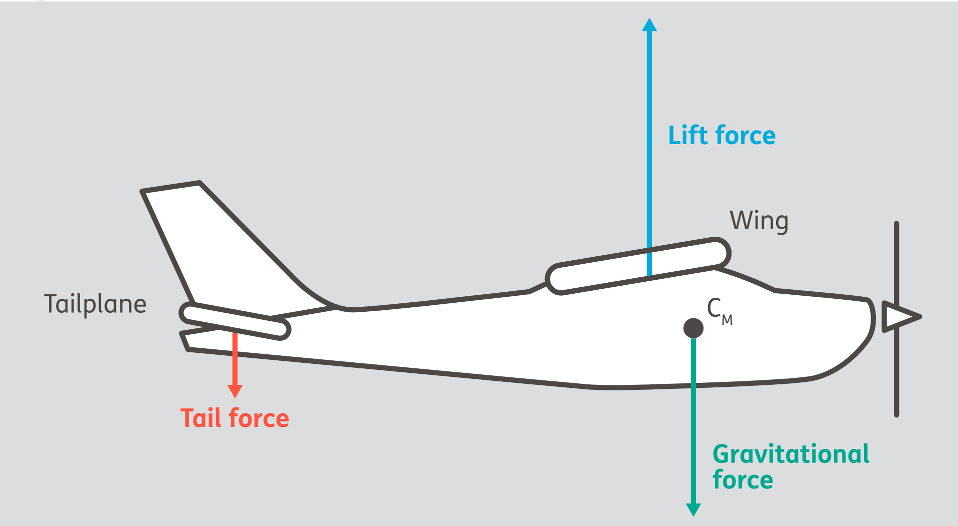
ABOUT PITCH STABILITY AND CONTROL

Depending on students' age and ability, you may want include more discussion about moments and how these relate to aircaft stability and flight control.

FIGURE 2:
FORCES AND MOMENTS

An aircraft in flight pivots around its centre of mass.

To remain level the clockwise moment created by the lift force must be balanced by the anticlockwise moment created by the tail force.



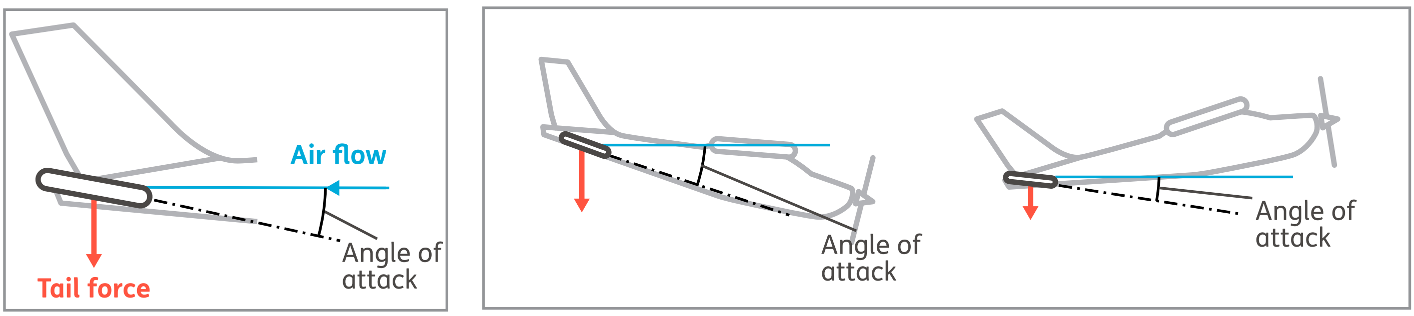
The vertical forces acting on an aircraft in steady flight are shown above (figure 2). The gravitational force acts downwards at the C_M, and the lift force due to the wings acts upwards. Aircaft designers need to bear in mind that it is not possible to keep the position of the C_M fixed because people move around and fuel mass is burned. This means that the gravitational force may not have the same line of action as the lift force, resulting in a turning moment: the lift force will cause the aircraft to rotate around C_M and pitch nose up or down.

For stability, aircraft engineers design aircraft to have a forward C_M. They also use a small upside-down wing, called a tailplane, at the rear of the aircraft to provide a balancing moment. The size of the downward force provided by the tail varies with the angle of the aircraft (see figure 3). If a disturbance (eg turbulence or passengers moving around) makes the nose pitch down a little, the tailplane's angle of attack increases, increasing the tail force and so creating a moment that will pitch the nose back up again.

If a disturbance pitches the nose up, the tail force decreases, and once again there will be an unbalanced moment that will tend to return the aircraft to level flight. You could talk about this being a negative feedback loop.

Pitch control is provided by small movable flaps in the tailplane called elevators (see figure 4). These can be used by the pilot to deliberately increase or decrease the tail force in order to change the pitch of the aircraft.

FIGURE 3: TAIL FORCE AND ANGLE OF ATTACK



Left: A tailplane's (or wing's) angle of attack is the angle it makes to the incoming air when the aircraft is in motion. To produce a downward tail force, a tailplane with a negative angle of attack is used.

Right: If the tailplane's angle of attack increases, air is deflected more strongly upwards and the tail force increases. If the tailplane's angle of attack decreases, the tail force decreases.

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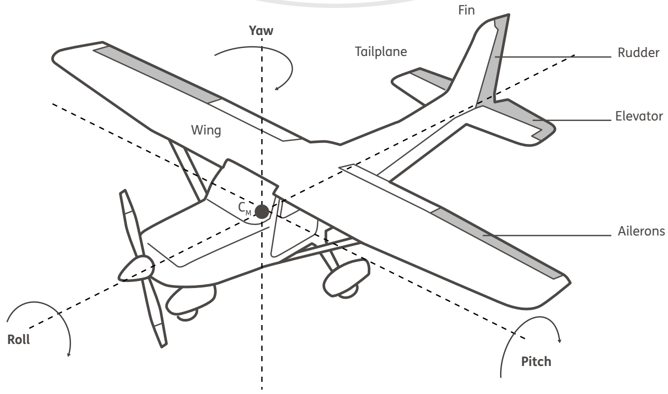
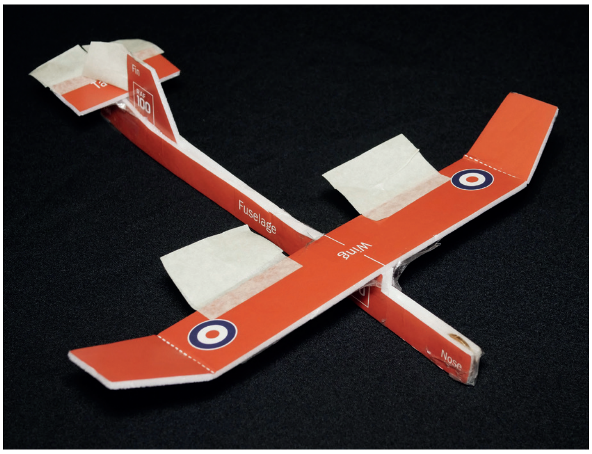
EXTENSION: FLIGHT CONTROL

As an extension, students can make control surfaces for their glider and investigate how these can be used to change the orientation of an aircraft.

FIGURE 4: CONTROL SURFACES AND FLIGHT AXES





Left: Flight axes (pitch, roll and yaw) and control surfaces (elevators, ailerons and rudder).

Right: Students can create control surfaces for their glider by adding masking tape.

Each student will need a copy of the extension sheet. Emphasise that although control surfaces are often integrated into the surfaces of aircraft, they do not need to do this for their glider. They should not cut the foam. Instead, they should use sticky or masking tape to make control surfaces that 'stick-out' from the tailplane, wings and fin (see figure 4 above).

They should start by making and testing elevators. Pushing the elevators up will cause the air to be deflected more strongly upwards, increasing the tail force and so should cause their glider to pitch nose up. Pushing the elevators down has the opposite effect; it decreases the tail force and so should cause their glider to pitch nose down.

The ailerons change the component of the lift force provided by each of the wings. When an aileron points downwards, it increases the force on that wing. The converse occurs when an aileron points upwards. By pointing the ailerons on each wing in opposite directions the glider should roll.

The rudder controls the aircraft in the yaw axis. Turning the rudder left turns the aircraft left, turning it right turns the aircraft right. By using the rudder and ailerons together students should be able to perform a banked turn.

MAKING THE HISTORY CONNECTION

The linked history activity is designed to show how technology was used in the past. The history activity here is about the origins of the RAF and the First World War. Team up with a history teacher to help students explore the early use of aircraft by the RAF.

FURTHER INFORMATION

To help students do their own research into forces of flight, explain that the aircraft engineers sometimes refer to the centre of mass as the centre of gravity, and that the gravitational force is also known as the weight.

Direct them to NASA's educational website as a starting point: **bit.ly/RAF-Forces**. For information about teaching moments see Supporting Physics Teaching (14-16): **bit.ly/RAF-Levers**.

For more information about how wings generate lift see Physics Education (Volume 38, Number 6): **bit.ly/RAF-Wings**.