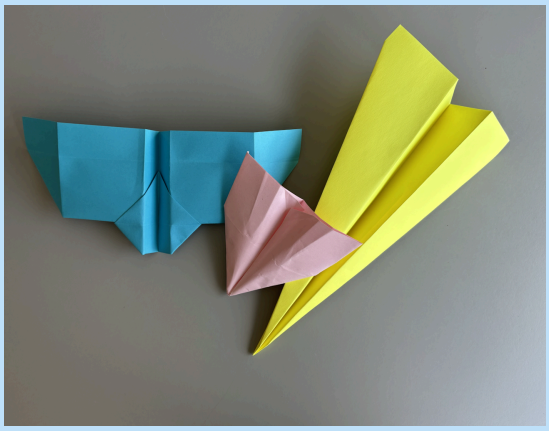
Dragonfly Flight: Gliding

SPS SOCK 2024

This demonstration is about what makes things fly and what gliding is. It centres a discussion on gliding dragonflies and asks participants to try and make paper airplanes that can glide as far as a dragonfly.



PRESENTER BRIEF

Presenter should know about the forces involved in flight and gliding and other basic aerodynamics.

Number of Participants: 10 to 15
Audience: Elementary to High School
Duration: 20 minutes
Difficulty: Level 1

MATERIALS REQUIRED

- Construction paper
- Printer paper
- Scissors
- Small weights (paperclips, coins)
- Tape
- Measuring tape
- Outdoor space or long hallway

VOCABULARY

Lift: a force from the interaction of fluid and an object, perpendicular to the direction the flow is moving in; lift often points upwards
Weight: the force of gravity; it pulls something downwards, towards the centre of Earth
Drag: the force that acts opposite to the direction of movement
Thrust: the force that pushes a flying thing in the direction it is moving in
Gliding: type of flight that has no thrust; where things sink through the air at a rate where they are moving more horizontal than vertically
Lift-to-drag ratio: the lift generated by a wing divided by the drag it creates moving through the air
Glide ratio: the distance travelled forward divided by how much an object descends

Angle-of-attack: the angle between the gliding object and the flow of the air.

USEFUL EQUATIONS

Glide ratio $\frac{distance\ travelled\ forwards}{altitude\ lost\ in\ that\ distance}$

Aspect ratio $\frac{4R^2}{S}$

R is the wing length

S is the area of both wings in a pair

ADDITIONAL RESOURCES

This demo pairs well with *Dragonfly Flight: Vortices* and *Dragonfly Muscles: Forces and Movement* from SPS SOCK 2024.

Some additional resources are:

- 'A Small Dragonfly Is Found to Be the World's Longest-Distance Flyer' Rutgers article

Current literature for presenters:

- Dragonfly flight: morphology, performance and behaviour (Wootton, 2020)
- Beyond the wing planform: morphological differentiation between migratory and nonmigratory dragonfly species (Suárez-Tovar et al., 2016)
- Dragonfly Flight: I. Gliding Flight and Steady-State Aerodynamic Forces (Wakeling and Ellington, 1997)
- On the Aerodynamic Performance of Dragonfly Wing Section in Gliding Mode (Anwer et al., 2013)
- Flight of the dragonflies and damselflies (Bomphrey et al., 2016)

Setup:

1. Make paper airplanes.
    a. Bat Paper Airplane
    b. 2023 Foldable Flight Paper Airplane Designer Contest Winners
    c. 2022 Foldable Flight Paper Airplane Designer Contest Winners
    d. 2012 World Record Paper Airplane
2. Record the heights they are throwing airplanes from (arm height). When they throw the airplanes, record how far the planes are gliding.
    a. Calculate glide ratios for each throw, using the heights they are throwing airplanes from divided by how far the planes go before they hit the ground.
    b. See if the airplanes can glide further than *Aeshna* dragonflies [see explanations below]
3. Make modifications to the planes to see if they can glide further.
    a. Some suggestions are: modifying wing shape, adding a weight to change the centre of gravity, corrugating the wings, using paper of different weights and

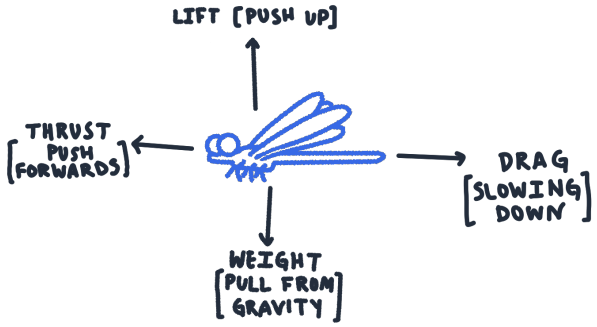
shapes.

Physics and Explanation:

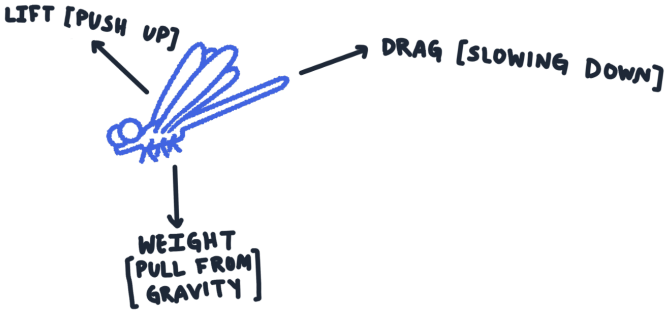
Elementary (ages 5-10):

Four forces affect things that fly: lift, weight, thrust, and drag. **Lift** is a force that pushes something upwards. **Weight** is a force from gravity. It pulls something downwards, towards the centre of Earth. **Thrust** is the force that pushes a flying thing in the direction it is moving in. **Drag** is a force that slows something down. Different kinds of material create different amounts of drag. For example, it is harder for you to walk through a swimming pool than to walk through the air. This is because water causes more drag than air. Flying insects use their wings to create both lift and thrust.

Ask students what other things use thrust, lift and drag (ex., airplanes, boats). How do they experience these forces in their lives?



Gliding is a type of flight without thrust – there is nothing that keeps pushing them forward. When things glide, they sink through the air at a rate where they are moving more horizontally than vertically. Some things that do gliding flight are hang gliders, paper airplanes, birds like the albatross and frigatebirds, flying squirrels, and dragonflies.



Some things glide more efficiently than others. More efficient gliding means they travel further forward than they fall downward. We can measure this efficiency with a **glide ratio,** which is the distance travelled forward divided by how much an object descends. A higher glide ratio is more efficient gliding, meaning the object can travel further with the same amount of energy.

Insects such as dragonflies may glide for many reasons. Migrating dragonflies often glide.

Gliding might help them use less energy because they don't have to keep flapping their wings. Some dragonflies can glide for up to 30 seconds without losing any height.

Many things impact how well a dragonfly can glide – how efficient their gliding can be. Some of these are the body proportions and wing shapes of the dragonfly. Dragonflies that have very long torsos have more drag, which makes them slow down faster. Dragonflies with wider wings usually do more gliding. Dragonflies with longer wings may be more agile.

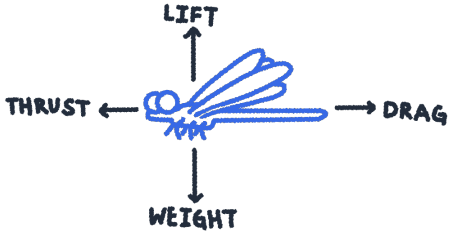
Have participants do the demo. What changes could they make to create airplanes that glide better? Who can make the airplane that glides the farthest?

- There are four forces that affect things that fly.
- Gliding is a type of flying where things are falling through the air in a way where they move more horizontal than vertically.
- Things like body proportions and wing shapes can change how well things can glide.

Middle School (ages 11-13) and general public:

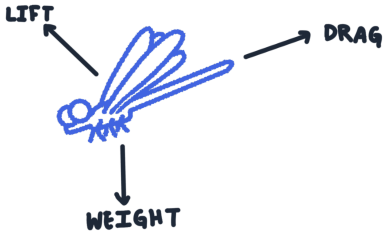
Four forces affect things that fly: lift, weight, thrust, and drag. **Lift** is an aerodynamic force from the interaction of fluid and an object. It points at a right angle to the direction of motion. **Weight** is the force of gravity. It pulls something downwards, towards the centre of Earth. **Thrust** is the force that pushes a flying thing in the direction it is moving in. **Drag** is the force that acts opposite to the direction of movement. When something is flying at a constant speed, these forces cancel out. Lift and weight are equal, and thrust and drag are equal. These four forces are unbalanced when an object isn't moving at a constant speed. Some examples are when something is taking off, landing, speeding up, slowing down, or turning. Flying insects use their wings to create both lift and thrust.

Ask students what other things use thrust, lift and drag (ex., airplanes, boats). How do they experience these forces in their lives?



Gliding is a type of flight where things sink through the air at a rate where they are moving more horizontally than vertically. They only move upwards when they fly through air that is rising faster than the rate they are sinking. Gliding objects have no thrust, so there is nothing that keeps continuously pushing them forward. Because of this, gliding things are constantly losing energy to drag. In steady gliding flight, the lift and drag acting on an object balances its weight.

Ask students for examples of things that glide. Can they describe how these objects or animals don't use thrust?



We measure gliding efficiency in many ways. One of these is a **lift-to-drag ratio.** This is the lift generated by a wing divided by the drag it creates moving through the air. This value is calculated for a specific airspeed and is from both the drag of the body and by the induced drag that comes with creating lift. When something glides at a constant speed, the lift-to-drag ratio is the same as the **glide ratio**–the distance travelled forward divided by how much an object descends.

Insects such as dragonflies may glide for a variety of reasons. Migratory dragonfly species are gliders, which may be an energy-saving flight strategy. Gliding dragonflies also move quickly through the air without their muscles producing heat. This may help them thermoregulate, maintaining a constant body temperature. The Wandering Glider, *Pantala flavescens,* can glide at 15 m/s for 10 to 15 seconds. Dragonflies in the *Aeshna* genus can glide for up to 30 seconds without losing altitude.

Several structural things influence how well dragonfly species glide: how much weight the wing can carry, the veins and corrugation on the wings, and the body proportions and wing proportions of the dragonfly. Dragonflies with disproportionately long abdomens will have higher drag. The veins and corrugation of the wings impact its stiffness and may impact drag and lift. Wing proportions are very important – species that do a lot of gliding have broader wings, and longer wings may increase manoeuvrability.

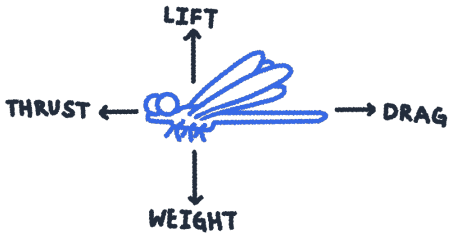
Have participants do the demo. What changes could they make to create airplanes that glide better? What are the effects of the changes they are making? Who can make the airplane that glides the farthest?

- There are four forces that affect things that fly: lift, weight, thrust, and drag.
- Gliding is a type of flight where things sink through the air at a rate where they are moving more horizontal than vertically.
- We measure gliding efficiency in many ways.

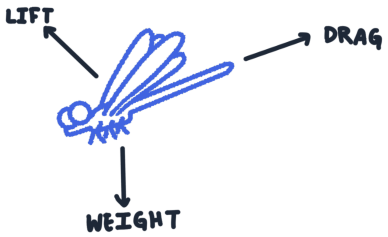
High School (ages 14+):

Four forces affect things that fly: lift, weight, thrust, and drag. **Lift** is an aerodynamic force from the interaction of fluid and an object. It points at a right angle to the direction of motion. The magnitude of lift depends on shape, size, and velocity. Wings create lift. Lift acts through the

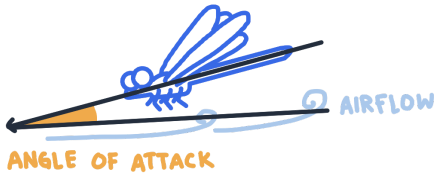
centre of pressure. **Weight** is the force of gravity. It pulls something downwards, towards the centre of Earth. The magnitude of weight depends on the mass of the object. For flying things, we think of weight as being collected around one point called the centre of gravity. The centre of gravity is the point the object rotates around in flight. **Thrust** is the force that pushes a flying thing in the direction it is moving in. **Drag** is the force that acts opposite to the direction of movement. Like lift, the shape and velocity of the objects influence drag. The thickness of the fluid the object moves through, like the 'stickiness' of the air, also impacts how much drag is created. When something is flying at a constant speed, these four forces cancel out. Lift and weight are equal, and thrust and drag are equal. However, when something is taking off, landing, speeding up, slowing down, or turning, the forces are unbalanced.



Gliding is a type of flight where things sink through the air at a rate where they are moving more horizontally than vertically. They only move upwards when they fly through air rising faster than the rate they are sinking. Gliding objects have no thrust, so there is nothing that keeps continuously pushing them forward. Because of this, gliding things are constantly losing energy to drag. In steady gliding flight, the lift and drag acting on an object balances its weight. The lift does not point directly vertically because it points at right angles to the airflow below the gliding object.



We measure gliding efficiency in many ways. One is an **angle of attack** or the angle between the body and the airflow. One of the measurements is a **lift-to-drag ratio**–the lift generated by a wing divided by the drag it creates moving through the air. This value is calculated for a specific airspeed and is from both the drag of the body and the induced drag that comes with creating lift. For a glider at a constant speed, the lift-to-drag ratio is the **glide ratio**–the distance travelled forward divided by how much an object descends.



Insects such as dragonflies may glide for a variety of reasons. Migratory dragonfly species are gliders, which may be an energy-saving flight strategy. Gliding dragonflies also move quickly through the air, allowing their body convection currents moving through the air to cool their bodies without their muscles producing heat. This may help them thermoregulate, maintaining a constant body temperature. The Wandering Glider, *Pantala flavescens,* can glide at 15 m/s for 10 to 15 seconds. Dragonflies in the *Aeshna* genus can glide for up to 30 seconds without losing altitude.

Ask the students why they think insects glide.

Several structural variables influence how efficiently dragonfly species glide: how much weight the wing can carry, the veins and corrugation on the wings, and the dragonfly's body and wing proportions. Dragonflies with disproportionately long abdomens will have higher drag. The veins and corrugation of the wings impact its stiffness and may impact drag and lift. Wing proportions are very important. Species that glide a lot have broader wings, and longer wings may increase manoeuvrability. Wing proportions are often described with an aspect ratio, a relationship between the length and average width of the wing. The aspect ratio is given by the equation $\frac{4R^2}{S}$ where 'R' is the wing length and 'S' is the area of both wings in a pair. High aspect ratios mean a high ratio of lift to drag, meaning the object can fly more efficiently for longer ranges with less drag slowing its forward motion.

Have participants do the demo. What changes could they make to create airplanes that glide better? What are the effects of the changes they are making? Who can make the airplane that glides the farthest?

- There are four forces that affect things that fly: lift, weight, thrust, and drag.
- Gliding objects have no thrust.
- Gliding motion can be described with angle-of-attack, lift:drag ratios, and glide ratios.
- There are structural variables that influence how efficiently things glide.