

SCIENCE ACTIVITY

Camber & Angle of Attack

Camber refers to the curvature of a wing. An efficient camber results in a wing with very little drag, requiring less thrust to achieve lift. In addition to reducing drag, camber also has an effect on lift. Although the Wrights never considered the 18th century theory of Daniel Bernoulli, referred to as the **Bernoulli Principle**, it was generally understood by those investigating flight in the late 19th century that cambered wings were more efficient than flat wings. Bernoulli, whose work was based on Newton's, demonstrated that the pressure of a fluid is lower when it is moving faster. Air (a fluid) passes faster over the top of a wing, resulting in lower pressure. Camber increases this effect. Therefore, cambered wings lift more easily than flat wings.

The Wright Brothers were inspired by the work of Otto Lilienthal, whose glider had a camber of 1 in 12 (the height of the center of the airfoil was 1/12th the distance measured from the front to the back of the airfoil). Although Lilienthal's work was revolutionary, the Wrights discovered that his data were flawed.

The Wrights were determined to find the most efficient camber for their glider. So, they spent a great deal of time testing different cambers. In fact, they tested about 200 different model wings when they performed wind tunnel experiments in 1901. Orville noted, "Earlier experimenters had so little accurate knowledge concerning the properties of cambered surfaces that they used cambered surfaces of great inefficiency, and the tables of air pressures which they possessed concerning cambered surfaces were so erroneous as to entirely mislead them. . . . I believe we possessed in 1902 more data on cambered surfaces, a hundred times over, than all of our predecessors put together."

Angle of Attack is the angle at which the air strikes the wing. In some textbooks and general references, Bernoulli's Principle is the sole explanation of lift. However, this explanation is incomplete. Newton's Third Law of equal and opposite forces must also be considered. (**Newton's Third Law**: For every action force there is an equal and opposite reaction force.) A wing deflects air downward because of its camber and angle of attack. This creates a reaction force of lift.

To better understand camber and angle of attack, and experiment with different **wing shapes** and **angles of attack**, click below for two interactive experiments produced by NASA using the Wright Brothers' airplane design.

Camber experiment: <http://www.grc.nasa.gov/WWW/Wright/airplane/shape.html>

Angle of Attack experiment:
<http://www.grc.nasa.gov/WWW/Wright/airplane/incline.html>