Part 2. How Airplanes Fly: Three Descriptions

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Today, compared to the earlier days of aviation, almost everyone has, or will, fly in an airplane. And, at one time or another we ask the question “why, or how, do wings make flight possible”? There are actually three possible answers and one is misleading, another wrong, and one that accurately describes the physics of developing lift. Lift is actually pretty easy to measure, but harder to get a clear understanding of and the popular explanation is misleading at best. This article will dispense with complicated mathematic equations because the intention is to understand the basic physics of flight.

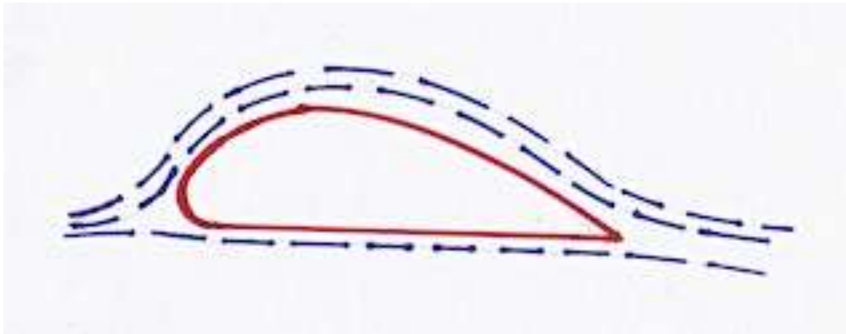
In the simplest terms we will show that the popular explanation that most of us were taught is misleading at least and lift is due to the wing diverting air downward.

The first definition of lift we can call **The Mathematical Aerodynamics Description** which uses complex mathematical computational models and simulations normally used only by aeronautical engineers to calculate the lift of a given wing design. Since we are interested in a simplified description of lift this method is not very useful to the average modeler or passenger trying to get an intuitive understanding of aerodynamic lift and flight.

The second definition described as **The Popular Explanation,** which is based on the *Bernoulli Principle* that has been used for many years to teach pilots “how airplanes fly”. The most unfortunate part of this theory is that it uses the “principle of equal transit times” which turns out to be wrong. It focuses on the shape of the wing and prevents understanding conditions such as inverted flight, ground effect, power, and the dependence of lift on the angle of attack of the wing relative to line of flight.

Bernoulli’s Principle says that as airspeeds go up the pressure is lowered. True, in air as well as liquid flow. So, if air speeds up over the wing to provide equal transit times over the convex airfoil from leading edge to trailing edge, it lowers pressure over the top of the airfoil and produces lift. You could wonder “why does the air flow faster over the top of an airfoil”?

The argument is that the air must speed up over the top of the airfoil as it travels farther than the air molecules flowing under the flat bottom of the airfoil for the molecules to converge with the air molecules from above the airfoil. The problem here is that the pressure reduction from the acceleration of the air molecules is less than previously thought and that to generate the required lift for a *small* airplane from Bernoulli’s Principle, the airfoil would have to have the distance over the top of the wing about 50% longer than the under the bottom of the wing. This would require an airfoil with a huge increase in thickness of the wing. Imagine the thickness needed to provide lift for a 747?



Required airfoil for light aircraft per Bernoulli's Principle

On the other hand, using the current light aircraft airfoils with an upper surface only about 1.5 – 2.5% longer than the lower surface, the airspeed would have to be over 400 MPH to produce enough lift to take-off. There is a flaw in the Popular Explanation?

So, is there any explanation that says separated air at the front of a wing must meet at the trailing edge at the same time? Actual modern wind tunnel test show the airflow under the airfoil is *slowed down* from the "free-stream" velocity of the air. Some degree of obstruction resulting in slowing is caused by the angle of incidence of the airfoil relative to the free-stream of airflow.

We can see that Bernoulli's Principle has some bearing on production of lift, but is incomplete at best. It does not explain acrobatic maneuvers such as inverted flight, or how a wing adjusts for great changes in load when pulling out of a dive or in a steep turn.

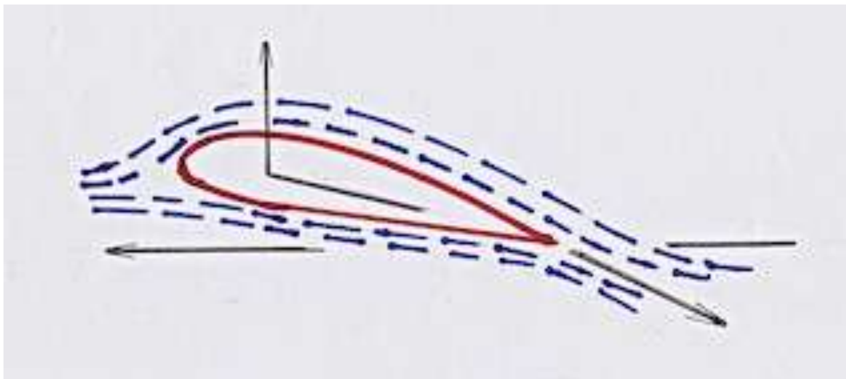
The Popular explanation ignores the work being done by the wing. Lift requires Power, or, work over time. While there are many interesting aspects *lift*, understanding the effect of power and drag is fundamental.

Yet, this is the explanation found in the pre-eminent pilot training book. The last printing of "Modern Airmanship" was in 1966.

The third definition uses **Newton's laws and Lift** primarily his First and Third laws with his second law later. Newton's first law states *a body at rest will remain at rest, and a body in movement will continue in straight-line motion unless subjected to an external applied force*. For us, it means that if we see airflow 'bending', or, if air is accelerated into motion there is force acting on it. Newton's third law states *for every action there is an equal and opposite reaction.* In order for the wing to produce lift it must do something to the air. The wing doing something to the air is the action while lift is the reaction.

As his law dictates, Newton's law makes a change in the momentum of the airflow resulting in force applied to the wing. To generate lift the wing must divert air molecules down, lots of air molecules, to produce that equal reaction upwards as lift.

We require a certain amount of lift to maintain altitude, more lift to climb, and less lift to descend. Parked, or at taxi speeds, gravity provides a downward force and the Ground provides an upward force equal to the weight of the aircraft to stay in one place. But you knew that.



Newton airflow pattern
Black vertical line shows Lift.
Horizontal black line shows Flight Path, and
black line off trailing edge shows Downwash.

The lift obtained from a wing is equal to the change in momentum of the air it diverts downward. Momentum is the product of mass times velocity. *The lift of a wing is proportional to the amount of air diverted downward times the downward velocity of the air.* This is an alternate form of Newton's second law. More lift requires either diverting more air, or increasing the velocity of the air being diverted. This downward airflow has a name: downwash.

Strangely, this theory of lift was well documented by V.E.Clark, the man who designed the Clark 'Y' airfoil in his book "Elements of Aviation" An Explanation of Flight Principles-copyright 1928

I wanted to keep this information as simple as possible, but aerodynamic study can be very complex. Part three will define the function of Power, Gravity, and Drag on our models as well as on full-scale aircraft. We'll see how wing shape affects lift, and why.

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