Forces of Flight

There are four forces that act upon an aircraft during straight-and-level flight. They are lift, gravity, thrust, and drag. Lift counters gravity, and drag counters thrust. When all four forces are in balance, straight-and-level flight is sustained. Engine-powered gliders obtain thrust from the engine. Once in flight and the engine has been shut off, or the glider has been launched, towed, or winched, the need to obtain thrust is still there. The glider does this by converting the potential energy that it has accumulated into kinetic energy as it glides downward, trading height for distance. In essence, the gravity vector becomes the horizontal forward thrust vector component. We measure the force of gravity as the weight in pounds or kilograms. This explains why the faster the glider flies, the faster it also descends.

Figure 3-1 shows a basic vector diagram for an unpowered glider with all forces in equilibrium. The lift vector is effectively split into two components: one part is opposing the weight force (gravity in straight-and-level flight), and the other component of the lift vector opposes drag by supplying thrust by the conversion of potential energy of the elevated weight of the glider into kinetic energy. This conversion continues until the airframe comes to rest on the surface. A glider is always descending in the air. This allows development of thrust by the energy conversion process. The objective of a glider pilot is to remain in air rising faster than the glider must descend to maintain flying speed. The same is true for a powered aircraft with its engine turned off. These forces are explained in greater detail in the Pilot's Handbook of Aeronautical Knowledge (FAA-H-8083-25) and by examining Newton's laws of motion.

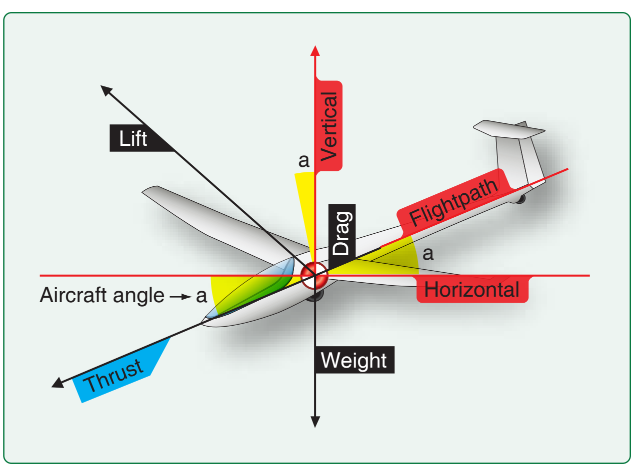

Figure 3-1. *Vector components of lift, drag, and weight (gravity).*

Newton's Third Law of Motion

According to Newton's Third Law of Motion, for every action there is an equal and opposite reaction. Thus, the air that is deflected downward also produces an upward (lifting) reaction. The wing's construction is designed to take advantage of certain physical laws that generate two actions from the air mass. One is a positive pressure lifting action from the air mass below the wing, and the other is a negative pressure lifting action from the lowered pressure above the wing.

As the airstream strikes the relatively flat lower surface of the wing when inclined at a small angle to its direction of motion, the air is forced to rebound downward, causing an upward reaction in positive lift. At the same time, airstream striking the upper curve section of the leading edge of the wing is deflected upward, over the top of the wing. The increase in airspeed on the top of the wing produces a sharp drop in pressure. Associated with the lowered pressure is downwash, a downward backward flow. In other words, a wing shaped to cause an action on the air, and forcing it downward, provides an equal reaction from the air, forcing the wing upward. If a wing is constructed in such form that it causes a lift force greater than the weight of the glider, the glider flies.

If all the required lift were obtained from the deflection of air by the lower surface of the wing, a glider would need only a flat wing like a kite. This, of course, is not the case at all. The balance of the lift needed to support the glider comes from the flow of air above the wing. Herein lies the key to flight. Lift is the result of the airflow above and over the wing lowering the air pressure above the wing, which pull the wing upwards and the downwash from below the wing pushing the wing upward. This fact must be thoroughly understood to continue in the study of flight.

Lift

Lift opposes the downward force of weight (gravity) and is produced by the dynamic effects of the surrounding airstream acting on the wing. Lift acts perpendicular to the flightpath through the wing's center of lift. There is a mathematical relationship between lift, angle of attack (AOA), airspeed, altitude, and the size of the wing. In the lift equation, these factors correspond to the coefficient of lift, velocity, air density, and wing surface area. These relationships are expressed in *Figure 3-2*. For a complete explanation of the lift formula and terms refer to the Pilots Handbook of Aeronautical Knowledge.

This shows that for lift to increase, one or more of the factors on the other side of the equation must increase. Lift is proportional to the square of the velocity, or airspeed; therefore, doubling airspeed quadruples the amount of lift if everything else remains the same. Likewise, if other factors remain the same while the coefficient or lift increases, lift also increases. The coefficient of lift goes up as the AOA is increased. As air density increases, lift increases. However,