The Pilot's Manual PM 2

Ground School

All the aeronautical knowledge required to pass the FAA Exams and operate as a Private and Commercial Pilot

Third Edition

Full-Color Edition!

Foreword by Barry Schiff

The Pilot's Manual 2: Ground School

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Contents

Weather

Flight Operations

Appendices

Forces Acting on an Airplane 1

Like all things, an airplane has *weight*, the force of gravity that acts through the center of the airplane in a vertical direction toward the center of the earth. While the airplane is on the ground, its *weight* is supported by the force of the ground on the airplane, which acts upward through the wheels.

During the takeoff roll, the task of supporting the weight of the airplane is transferred from the ground to the wings (and vice versa during the landing). While in level flight, the weight of the airplane is supported by the *lift* force, which is generated aerodynamically by the flow of air around the wings. In addition, as the airplane moves through the air it will experience a retarding force known as *drag*, which, unless counteracted, will cause the airplane to decelerate and lose speed.

In steady (unaccelerated) straight-and-level flight, the drag (or retarding force) is neutralized by the *thrust* (figure 1-2). In most smaller airplanes, thrust is produced by the engine–propeller combination; in pure-jet airplanes, the thrust is produced by the gas efflux, without the need for a propeller.

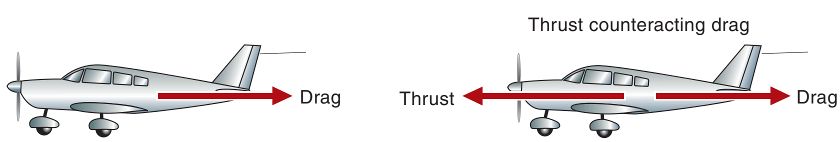

Figure 1-1 Drag counteracted by thrust.

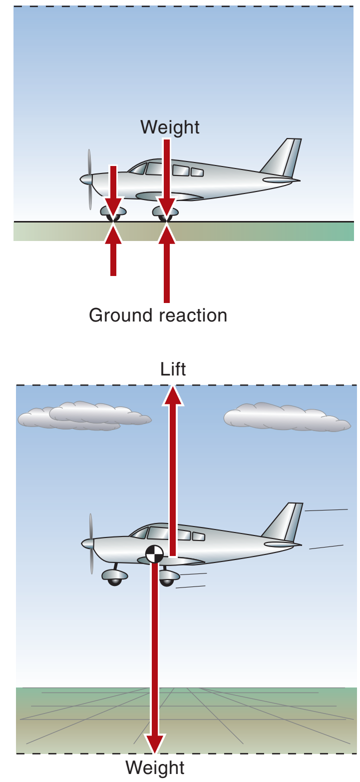

Figure 1-2
The airplane is supported by the ground, and in the air by lift.

In figure 1-3, the forces are equal and opposite, canceling each other out, so that the resultant force acting on the airplane is zero, and it will neither accelerate nor decelerate. In this situation the airplane is in a state of *equilibrium:*

- *weight* is equal to *lift*, and acts in the opposite direction; and
- *drag* is equal to *thrust*, and acts in the opposite direction.

During steady (unaccelerated) flight the four main forces are in equilibrium and the airplane will continue in level flight at the same speed.

For the type of airplane you are likely to be flying during your training, the amount of the lift (and therefore the weight) during cruise flight will be approximately 10 times greater than the drag (and thrust). This relationship of lift to drag is very important and is referred to as the *lift/drag ratio.* The L/D ratio in this case is 10 to 1.

If the airplane is to accelerate in level flight, the thrust must exceed the drag; if the airplane is to be slowed down in level flight, the thrust must be less than the drag. A state of equilibrium does not exist during acceleration or deceleration.

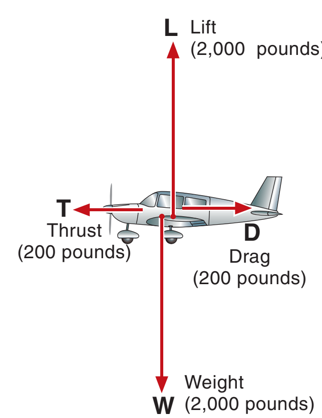

Figure 1-3 The four main forces are in equilibrium during unaccelerated flight.

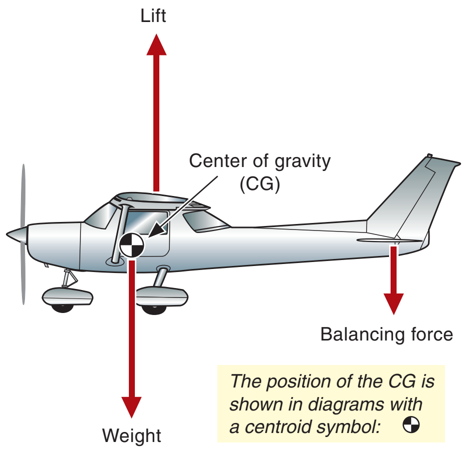

Figure 1-4
Weight acts downward through the center of gravity (CG).

Gravitational Force (Weight)

Gravity is the downward force attracting all bodies vertically toward the center of the earth. The name given to the gravitational force is *weight*, and for our purposes it is the total weight of the loaded airplane. This weight is called *gross weight*, and it may be considered to act as a single force through the *center of gravity* (CG).

The CG is the point of balance. Its position depends on the weight and position of the various parts of the airplane and the load that it is carrying. If the airplane were supported at its center of gravity, the airplane would be balanced.

The weight of an airplane varies depending on the load it has to carry (cargo, baggage, passengers) and the amount of fuel on board. Airplane gross weight will gradually decrease as the flight progresses and fuel is burned off. The magnitude of the weight is important and there are certain limitations placed on it—for instance, a maximum takeoff weight will be specified for the airplane. Weight limitations depend on the structural strength of the components making up the airplane and the operational requirements the airplane is designed to meet.

The balance point (center of gravity) is very important during flight because of its effect on the stability and performance of the airplane. It must remain within carefully defined limits at all stages of the flight.

The location of the CG depends on the weight and the location of the load placed in the airplane. The CG will move if the distribution of the load changes, for instance by transferring load from one position to another by passengers moving about or by transferring fuel from one tank to another. The CG may shift forward or aft as the aircraft weight reduces in flight, such as when fuel burns off or parachutists jump out.

CPL

Wing Loading

Both weight and balance must be considered by the pilot prior to flight. If any limitation is exceeded at any point in the flight, safety will be compromised. (A detailed study of weight and balance appears in chapter 11.) A useful means of describing the load that the wings carry in straight-and-level flight (when the lift from the wings supports the weight of the airplane) is *wing loading*, which is simply the weight supported per unit area of wing.

$$\text{Wing loading} = \frac{\text{weight of the airplane}}{\text{wing area}}$$

Example 1-1

An airplane has a maximum certificated weight of 2,600 pounds and a wing area of 200 square feet. What is its wing loading at maximum weight?

$$\text{Wing loading} = \frac{\text{weight}}{\text{wing area}} = \frac{2{,}600}{200} = 13 \text{ pounds/square foot}$$

End CPL

Airflow and Airfoils

An airfoil is a surface designed to lift, control, and propel an airplane. Some well-known airfoils are the wing, the horizontal stabilizer (or tailplane), the vertical stabilizer (or fin), and the propeller blades. A wing is shaped so that as the air flows over and under, a pressure difference is created—lower pressure above the wing and higher pressure below the wing—resulting in the upward aerodynamic force known as lift. The wing also bends the free stream of air, creating downwash. The total reaction has a vertical component to lift the aircraft or change its flight path, and it has a rearward component, drag, which resists the movement of the wing through the air.

The airplane's control surfaces—ailerons, elevator and rudder—form part of the various airfoils. You can move these to vary the shape of each airfoil and the forces generated by the airflow over it. This enables you to maneuver the airplane and control it in flight. These control surfaces also operate based on Newton's Third Law of Motion, which says that every action has an equal and opposite reaction. By deflecting the free stream of air that flows over them, control surfaces cause the airplane to roll, yaw or pitch as the reaction.

The wing shape can also be changed by extending the flaps to provide better low-speed airfoil characteristics for takeoff and landing.

Figure 1-5
Airfoil shape.

Figure 1-6
Left aileron.

Figure 1-7
Vertical stabilizer and rudder.

Figure 1-8
Wing flaps.

Airflow Around an Airfoil

The pattern of the airflow around an airplane depends on the shape of the airplane and its attitude relative to the airflow. There are two airflow types: streamline flow and turbulent flow.

Laminar Flow

If successive molecules or particles of air follow the same steady path in a flow, then this path can be represented by a line called a *streamline*. There will be no flow across the streamlines, only along them. There is no turbulence or mixing, hence the name *laminar* (layered) flow. At any fixed point on the streamline, each particle of air will experience the same speed and pressure as the preceding particles of air when they passed that particular point. These values of speed and pressure may change from point to point along the streamline. A reduction in the speed of streamline flow is indicated by wider spacing on the streamlines, while increased speed is indicated by decreased spacing of the streamlines. The existence of streamline flow is very desirable around an airplane because streamlined flow offers the least drag.

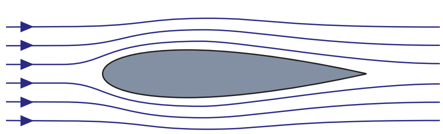

Figure 1-9 Laminar flow.

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