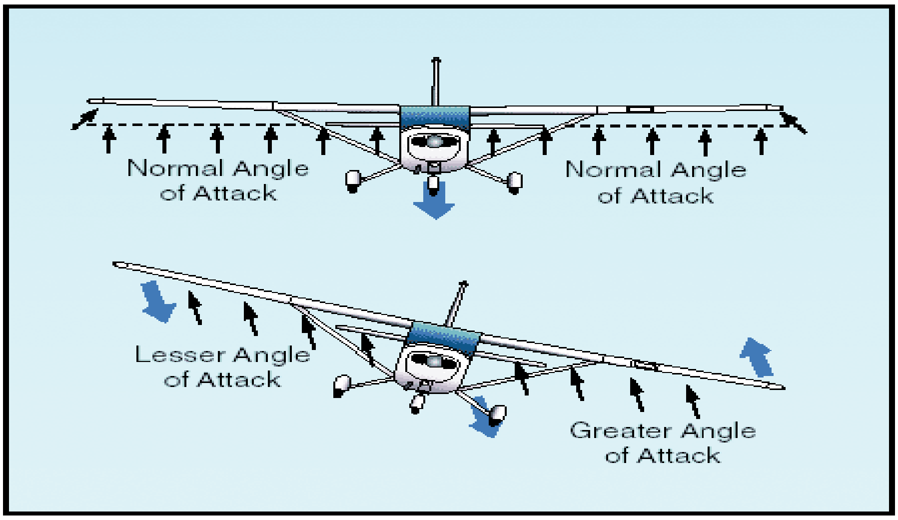
Lateral stability (rolling)

Stability about the airplane's longitudinal axis, which extends from nose to tail, is called lateral stability. This helps to stabilize the lateral or rolling effect when one wing gets lower than the wing on the opposite side of the airplane. There are four main design factors that make an airplane stable laterally: dihedral, keel effect, sweepback, and weight distribution. The most common procedure for producing lateral stability is to build the wings with a dihedral angle varying from one to three degrees. In other words, the wings on either side of the airplane join the fuselage to form a slight V or angle called "dihedral," and this is measured by the angle made by each wing above a line parallel to the lateral axis.

The basis of rolling stability is, of course, the lateral balance of forces produced by the airplane's wings. Any imbalance in lift results in a tendency for the airplane to roll about its longitudinal axis. Stated another way, dihedral involves a balance of lift created by the wings' angle of attack on each side of the airplane's longitudinal axis. If a momentary gust of wind forces one wing of the airplane to rise and the other to lower, the airplane will bank. When the airplane is banked without turning, it tends to sideslip or slide downward toward the lowered wing.



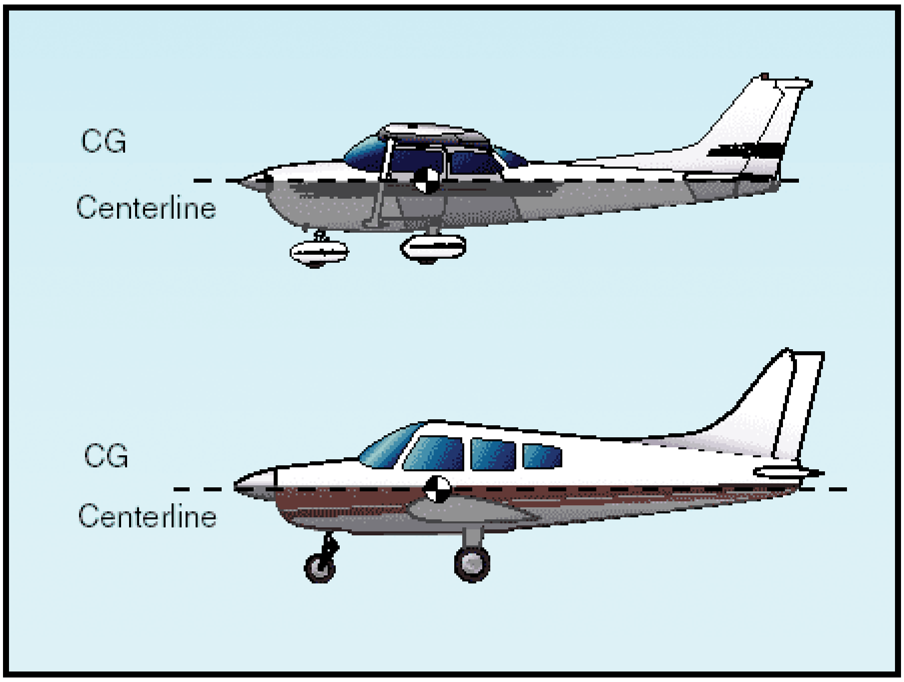
Dihedral for lateral stability.

Since the wings have dihedral, the air strikes the low wing at much greater angle of attack than the high wing. This increases the lift on the low wing and decreases lift on the high wing, and tends to restore the airplane to its original lateral attitude (wings level)—that is, the angle of attack and lift on the two wings are again equal.

The effect of dihedral, then, is to produce a rolling moment tending to return the airplane to a laterally balanced flight condition when a sideslip occurs.

The restoring force may move the low wing up too far, so that the opposite wing now goes down. If so, the process will be repeated, decreasing with each lateral oscillation until a balance for wings-level flight is finally reached. Conversely, excessive dihedral has an adverse effect on lateral maneuvering qualities. The airplane may be so stable laterally that it resists any intentional rolling motion. For this reason, airplanes that require fast roll or banking characteristics usually have less dihedral than those designed for less manoeuvrability.

The contribution of sweepback to dihedral effect is important because of the nature of the contribution. In a sideslip, the wing into the wind is operating with an effective decrease in sweepback, while the wing out of the wind is operating with an effective increase in sweepback. The swept wing is responsive only to the wind component that is perpendicular to the wing's leading edge. Consequently, if the wing is operating at a positive lift coefficient, the wing into the wind has an increase in lift, and the wing out of the wind has a decrease in lift. In this manner, the swept back wing would contribute a positive dihedral effect and the swept forward wing would contribute a negative dihedral effect. During flight, the side area of the airplane's fuselage and vertical fin react to the airflow in much the same manner as the keel of a ship. That is, it exerts a steadying influence on the airplane laterally about the longitudinal axis.Such laterally stable airplanes are constructed so that the greater portion of the keel area is above and behind the center of gravity.



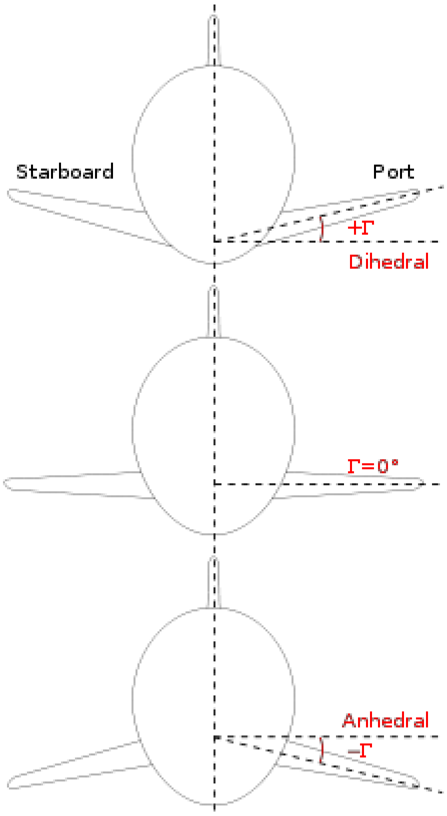
Keel area for lateral stability.

Thus, when the airplane slips to one side, the combination of the airplane's weight and the pressure of the airflow against the upper portion of the keel area (both acting about the CG) tends to roll the airplane back to wings-level flight.

TOPIC: ***DIHEDRAL EFFECT***

Dihedral angle (or anhedral angle) has a strong influence on **dihedral effect**, which is named after it. **Dihedral effect** is the amount of roll moment produced per degree (or radian) of sideslip. **Dihedral effect** is a critical factor in the stability of an aircraft about the roll axis (the spiral mode).

Dihedral angle is the upward angle from horizontal of the wings or tail plane of a fixed-wing aircraft. "Anhedral angle" is the name given to negative dihedral angle, that is, when there is a *downward* angle from horizontal of the wings or tail plane of a fixed-wing aircraft.



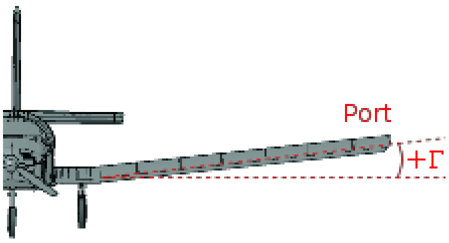
Schematic of dihedral and anhedral angle of an aircraft wing

Dihedral angle (or anhedral angle) has a strong influence on **dihedral effect**, which is named after it. Dihedral effect is the amount of roll moment produced per degree (or radian) of sideslip. Dihedral effect is a critical factor in the stability of an aircraft about the roll axis (the spiral mode). It is also pertinent to the nature of an aircraft's Dutch roll oscillation and to manoeuvrability about the roll axis.

Dihedral Angle is the upward angle from horizontal of the wings of a fixed-wing aircraft, or of any paired nominally-horizontal surfaces on any aircraft. The term can also apply to the wings of a bird. Dihedral Angle is also used in some types of kites such as box kites. Wings with more than one Angle change along the ful span are said to be *polyhedral*.

Dihedral Angle has important stabilizing effects on flying bodies because it has a strong influence on the dihedral effect.

Dihedral effect of an aircraft is a rolling moment resulting from the vehicle having a non- zero angle of sideslip. Increasing the dihedral angle of an aircraft increases the dihedral effect on it. However, many other aircraft parameters also have a strong influence on dihedral effect. Some of these important factors are: wing sweep, vertical center of gravity, and the height and size of anything on an aircraft that changes it's sideward force as sideslip changes.



Measuring the dihedral angle

Longitudinal dihedral is a comparatively obscure term related to the pitch axis of an airplane. It is the angle between the zero lift axis of the wing and horizontal tail. Longitudinaldihedral can influence the nature of controllability about the pitch axis and the nature of an aircraft's Phugoid-mode oscillation.

When the term "dihedral" (of an aircraft) is used by itself it is usually intended to mean "dihedral angle". However, context may otherwise indicate that "dihedral effect" is the intended meaning.

Dihedral angle on an aircraft almost always implies the angle between two paired surfaces, one on each side of the aircraft. Even then, it is almost always between the left and right wings. However, mathematically dihedral means the angle between any two planes. So, in aeronautics, in one case, the term "dihedral" is applied to mean the difference in angles between two front-to-back surfaces:

Longitudinal dihedral is the difference between the angle of incidence of the wing root chord and angle of incidence of the horizontal tail root chord.

Longitudinal dihedral can also mean the angle between the zero lift axis of the wing and tail instead of between the root chords of the two surfaces. This is the more meaningful usage because the directions of zero-lift are pertinent to longitudinal trim and stability while the directions of the root chords are not.

During design of a fixed-wing aircraft (or any aircraft with horizontal surfaces), changing dihedral angle is usually a relatively simple way to adjust the overall dihedral effect. This is to compensate for other design elements' influence on the dihedral effect. These other elements (such as wing sweep, vertical mount point of the wing, etc.) may be more difficult to change than the dihedral angle. As a result, differing amounts of dihedral angle can be found on different types of fixed-wing aircraft. For example, the dihedral angle is usually greater on low-wing aircraft than on otherwise-similar high-wing aircraft. This is because "highness" of a wing (or "lowness" of vertical center of gravity compared to the wing) naturally creates more dihedral effect itself. This makes it so less dihedral angle is needed to get the amount of dihedral effect needed.

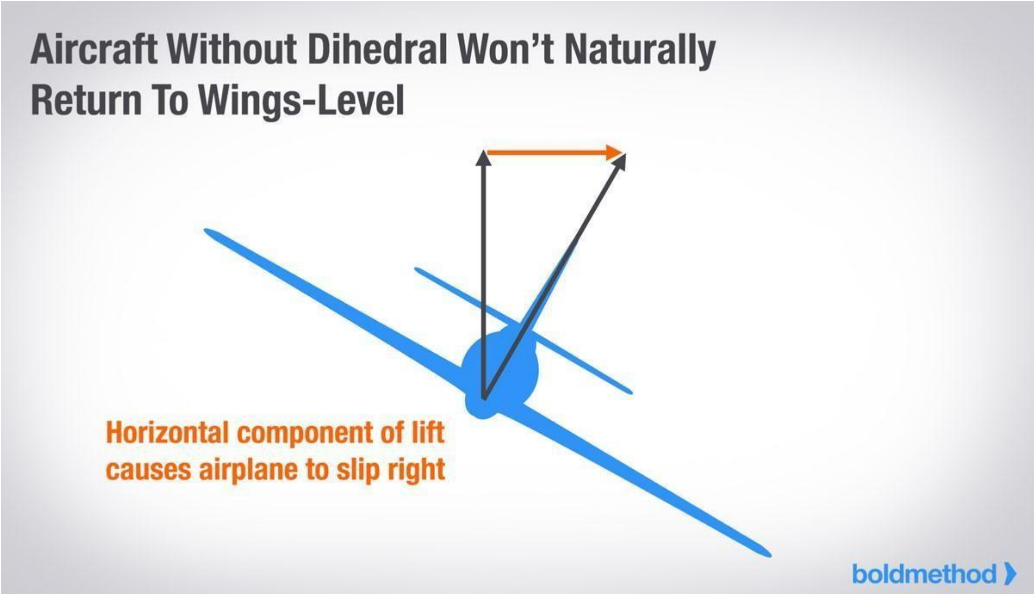
What's Dihedral?

Dihedral sounds like one of those words you cringed at in math class, but it's actually realy simple. Dihedral is the upward angle your aircraft's wings. Here's a great example ofwing dihedral on a Boeing 777:

See how the 777's wings angle upward? That dihedral makes the jet more laterally stable, or in other words, more stable when it rolls left or right. And it's not just large jets that have dihedral like this. It's found on almost every aircraft out there.

So Why Do You Need Dihedral?

It all comes down to stability. If you didn't have dihedral, you'd spend a lot of time keeping your wings level. Here's why: When you bank an airplane, the lift vector tilts in the same direction as the bank. And when that happens, your airplane starts slipping in the same direction, in this case, to the right.



The problem is, if you have a straight-wing aircraft, there's no force that will bring the airplane back to wings-level flight without *you* intervening. And while that may be good for an aerobatic aircraft or fighter jet, it's not something you want in your general aviation aircraft or airliner.

Here's How Dihedral Fixes The Problem

When you add dihedral, you add lateral stability when your aircraft rolls left or right. Here's how it works: let's say you're flying along and you accidentally bump your controls, rolling your plane to the right. When your wings have dihedral, two things happen:

1) First, your airplane starts slipping to the right. That means the relative wind is no longer approaching directly head-on to the aircraft, and instead is approaching slightly from the right. This means that there is a component of the relative wind that is acting inboard against the right wing.

2) Second, because the relative wind has the inboard component, and because the wings are tilted up slightly, a portion of the the relative wind strikes the underside of the low wing, pushing it back up toward wings level. What's really happening here is the low wing is flying at a higher AOA, and producing more lift.

The more dihedral your aircraft has, the more pronounced the effect becomes. But for most aircraft, they only have a few degrees of dihedral, which is *just enough* to return your wings to level during small disturbances, like turbulence, or bumping your flight controls in the cockpit.

It's Not All Good News - Dihedral Comes At A Cost

Dihedral isn't always good, and like almost every design factor, it comes with a cost. In this case, there are two costs: increased drag, and decreased roll rate.

Wings with dihedral don't produce lift completely vertically. There's a vertical component, and a horizontal component. So when you're flying straight and level, your lift is not 100% vertical.

And, the same dihedral effect that keeps your wings level in turbulence, works against you when you try to roll right or left. When you put an aircraft into a bank, the dihedral effect constantly tries to return your wings to level. And with enough dihedral, your roll rate can be dramatically decreased. While that's good for stability, it's bad for maneuvering.