EFFECTS OF CONTROLS - (Long Brief)

Aim:

To understand the basic aerodynamic principles, considerations and application of the primary and ancillary aircraft controls.

Objectives:

By completion of this brief you will be able to recall and recite how an aerofoil produces lift, and name the primary and ancillary controls. You will also be able to recall and recite applications of pilot inputs to these controls.

Revision:

Trial introductory flight (if applicable).

Definitions:

Dynamic pressure - pressure due to movement through the air. The faster an object travels through the air, the greater the dynamic pressure it experiences.

Static pressure - pressure of the atmosphere acting at right angles to a body.

Aerofoil - a body shaped to produce an aerodynamic reaction (lift) perpendicular to its direction of motion. The wings of an aircraft, for example, are aerofoils.

Applications:

The effects of controls lesson will lay the foundation for all future flying.

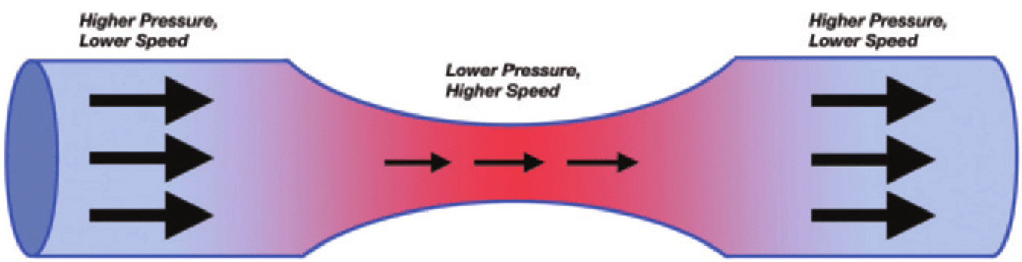
Principles:

The Production of Lift:

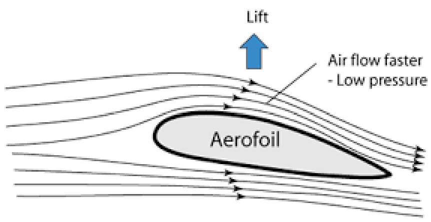
Lift is the aerodynamic force that results from moving an aerofoil through a fluid. When related to aeroplanes the fluid involved is air.
The generation of lift is an incredibly complex phenomena, and a complete understanding of how it is produced is outside the scope of this lesson. Despite this, pilots must have some (even if simplified) understanding of the production of lift, including the variables that influence it.

Lift is partially explained by the principles associated with Bernoulli's Theorem, which states that:

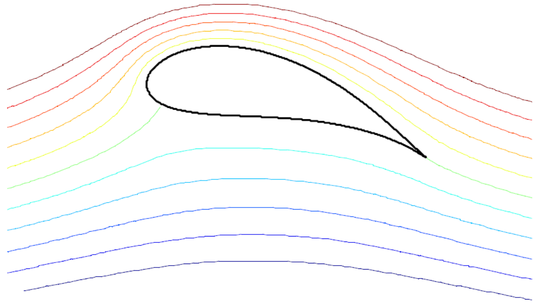
Total Pressure (a constant) = Dynamic Pressure (a function of speed) + Static Pressure



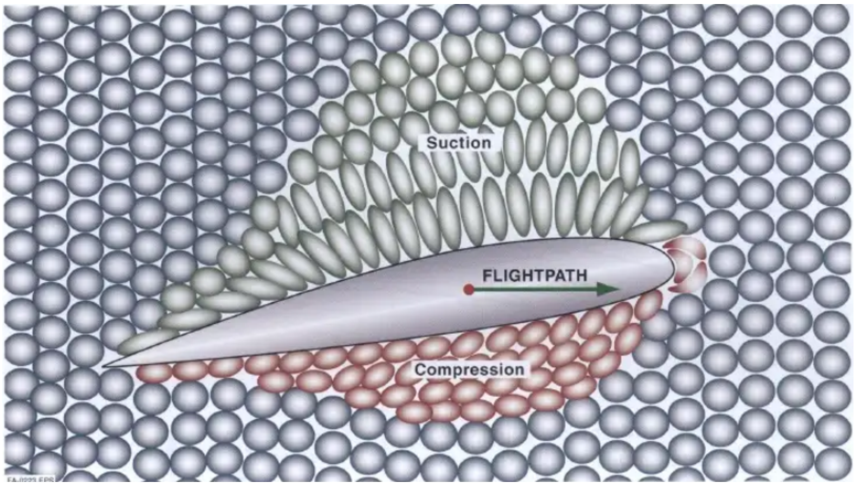
Air flows at a higher speed over the upper surface of the wing than the lower surface, and faster air exhibits higher *dynamic pressure* but exerts lower *static pressure.*
The lower static pressure on the upper surface, and higher static pressure on the lower surface, causes an upward reaction force.



One of the reasons air flows faster over the upper surface of the wing is because of *camber*, which is just another term for the curvature of the wing. Most aircraft wings are not symmetrical, and have some greater degree of curvature on their upper side. As air is forced over the curved surface on the top of the wing, it is pinched between the air above it, and the surface below. This constriction has the effect of speeding it up.

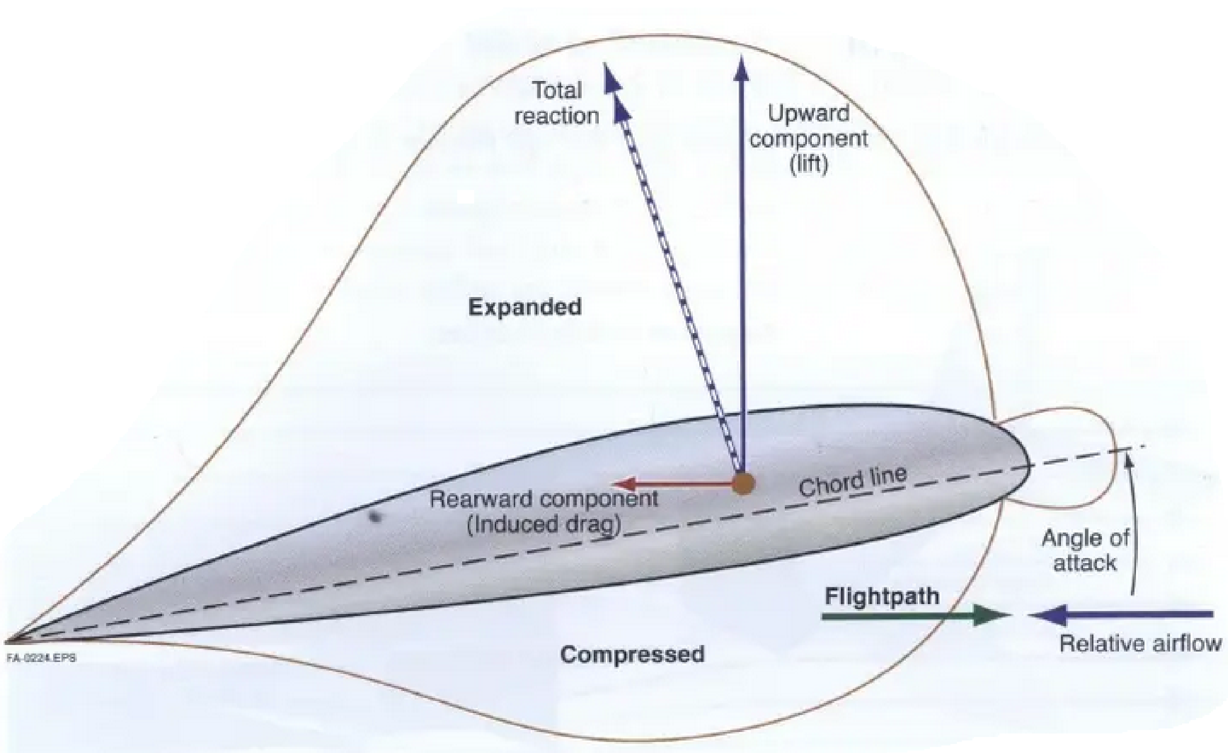


The pressure differential - and therefore lift - of an aerofoil is also a product of compression and suction effects.



As a wing moves through the air, it compresses the air molecules in front and below and creates an area of reduced pressure (suction) above and behind. The magnitude of this suction is proportional to the angle between the relative air, and the wing itself. The angle of attack.

The greater the angle of attack of an aerofoil, the greater the amount of compression on the lower surface and amount of suction on the upper surface - and consequently, the greater the total reaction force.



The Lift Formula:

$$L = C_L \frac{1}{2} \rho V^2 \mathbf{S}$$

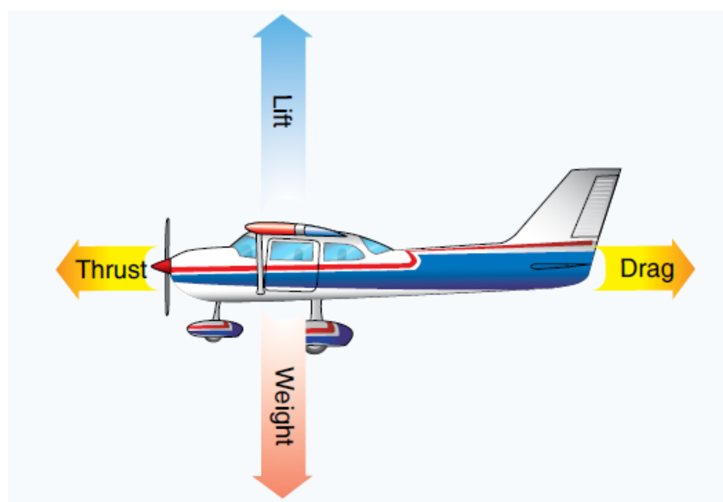
ϱ (rho) =	air density (affected by temperature and pressure of the atmosphere)
V (velocity) =	velocity of wing (relative to air parcel through which it is travelling)
CL (coefficient of lift) =	lifting ability of the wing (affected by camber and angle of attack)
S (wing area) =	surface area of aerofoil (not typically changeable in light training aircraft, but may be increased with use of fowler flaps and slats).

Changing one or more of the above components may increase (or decrease) the lift force.

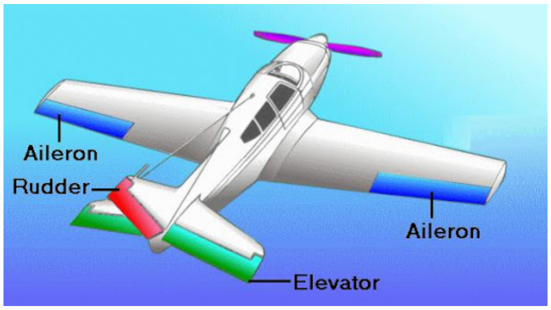
The Four Forces:

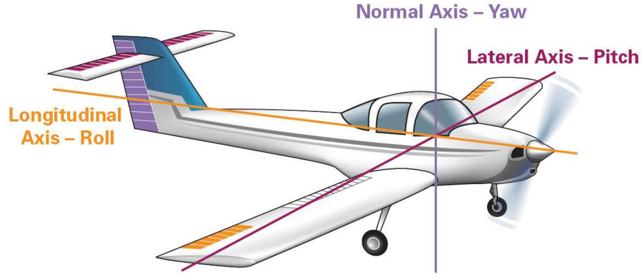
Greater detail on the four forces acting on an aircraft will be provided in subsequent lessons. However, it should be known that an aircraft experiences the forces of:

- Lift (as previously described).
- Weight (force due to gravity)
- Thrust (produced by the propeller)
- Drag (the resistance to motion through the air)



The Primary Flight Controls:

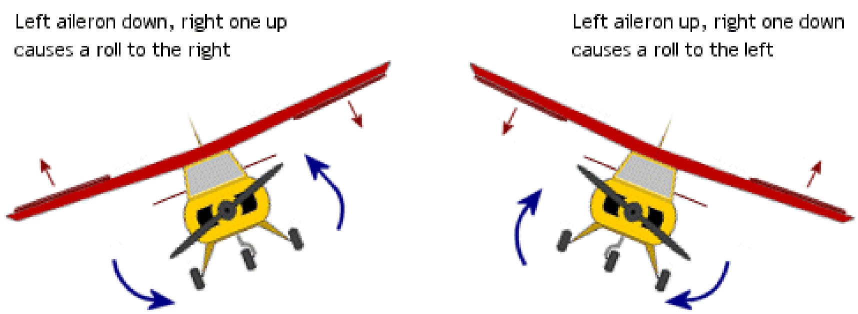




Ailerons:

The *primary effect of the ailerons* is to roll the aircraft about the longitudinal axis. In the aircraft, the pilot turns his or her control column to the left to initiate a left roll, and to the right for a right roll.

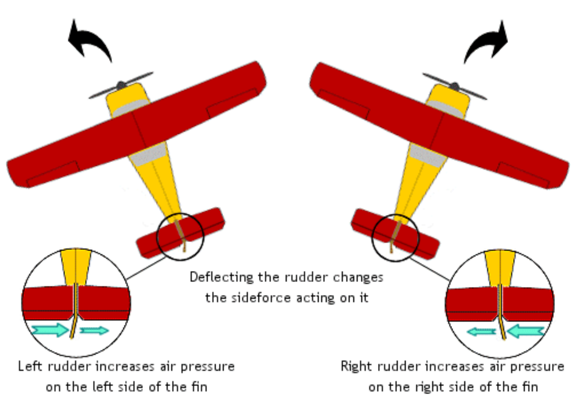
In initiating a left roll, the aileron on the left wing goes up and the aileron on the right wing goes down. The right wing - with the down going aileron - experiences greater lift and a roll to the left ensues.



The *secondary effect of the ailerons* is that the aircraft will tend to slip in the direction of the down-going wing, causing airflow to strike the vertical tailplane (keel surface) and yaw the aircraft about the normal axis.

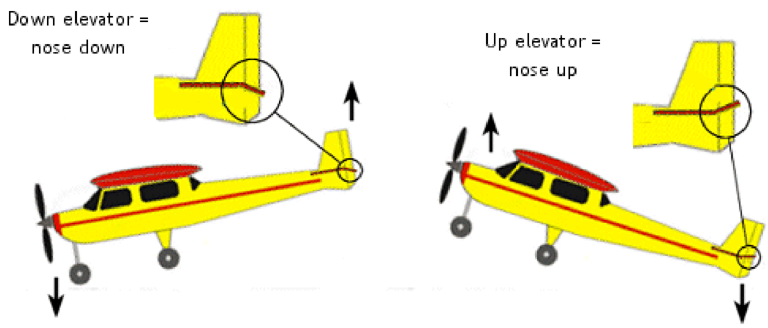
Rudder:

The *primary effect of the rudder* is to yaw the aircraft about the normal axis. The pilot's control of the rudder is through two (rudder) pedals located at the pilot's feet. Pressure on the left pedal will initiate a yaw to the left, and pressure on the right pedal will initiate a yaw to the right. The yaw is a result of the rudder on the aircraft's tailplane being deflected and generating an aerodynamic reaction force.



The *secondary effect* of rudder use is roll. Rudder yaws the aircraft about the normal axis which increases the speed of the outer wing relative to the inner wing. The faster travelling outer wing experiences more lift which induces a roll in the same direction as yaw.

Elevator:
The *primary effect of the elevator* is to pitch the nose of the aircraft either up or down about the lateral axis by producing an upwards or downwards force on the tailplane. In the aircraft, the pilot exerts backward pressure on the control column to pitch the nose up, and forward pressure on the control column to pitch the nose down.



There is *no secondary aerodynamic effect of the elevator*. Changing the aircraft's pitch, however, will have an effect on both airspeed and altitude. If the pilot were to pull back on the control column the aircraft would pitch up and the aircraft would simultaneously begin to gain altitude and lose speed.

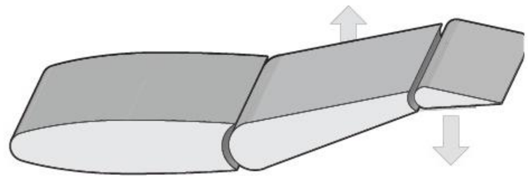
To summarise:

PRIMARY CONTROL SURFACE	PRIMARY EFFECT	SECONDARY EFFECT
Aileron	Roll	Yaw
Rudder	Yaw	Roll
Elevator	Pitch	N/A

Ancillary Controls

Trim:
Trim is the control that provides relief of control pressure to make the task of flying the aircraft easier for the pilot. In most light aircraft (including the Cessna C172) a trim tab, which is located on the trailing edge of the elevator, is deflected in the opposite direction to the elevator. It generates an aerodynamic force to help keep the elevator position in place, thus reducing the back or forward pressure required on the control column. Other aircraft may employ different mechanisms to achieve the same end result. The Piper Tomahawk (PA38), for example, uses a spring loaded system to assist the pilot in holding the elevator position in place.

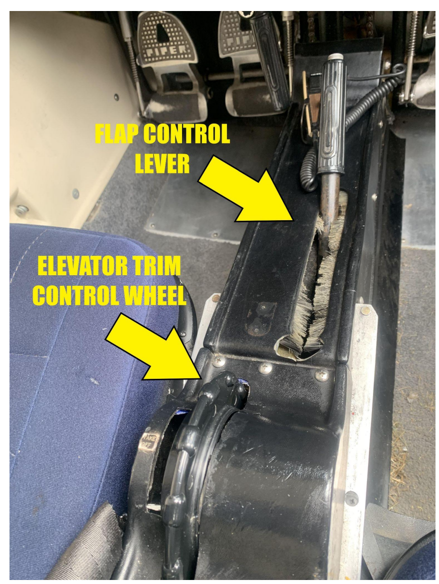
In any case, the trim is operated by means of a trim wheel located in the centre console which is rotated backwards to relieve back pressure and forwards to relieve forward pressure.



Flaps:
Flaps increase the camber of the wing. This increases the coefficient of lift for any given angle of attack, thereby allowing the aircraft to fly at slower speeds.
Refer Lift Formula:

$$L = C_L \frac{1}{2} \rho V^2 \mathbf{S}$$

Flaps also allow the pilot to fly at a lower nose attitude, increasing forward visibility, which is particularly useful on approach to land. When extended, flaps will typically generate a momentary ballooning effect on the aircraft due to the sudden increase in the amount of lift. This may require some forward pressure to compensate for until the increased drag from the flaps slows the aircraft down. Extending (and retracting) flaps will also generate a pitch change that the pilot will need to anticipate and compensate for. The magnitude and direction of the pitch change (nose up or down) will vary with aircraft design.



Flaps are extended and retracted in stages. The C172 allows flap extension to 10, 20, 30 and 40 degrees. The PA38 only provides 2 stages of flap extension i.e. 21 degrees and 34 degrees. Sudden retraction of all of an aircraft's flaps is inadvisable as the aircraft will start to sink due to the rapid loss of lift.

Throttle:

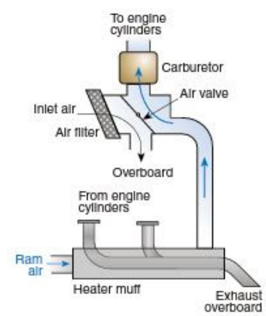
The throttle control is used by the pilot to regulate engine power. The throttle position governs the amount of fuel/air mixture delivered to the engine for combustion. To increase power push the throttle control toward the front of the aeroplane, and to reduce power pull it back towards the tail of the aircraft. An increase in power has a pitch up effect on the aircraft, and a decrease in power has a pitch down effect. Engine power can be gauged with reference to the tachometer which shows engine and propeller speed in revolutions per minute (RPM).

Mixture:

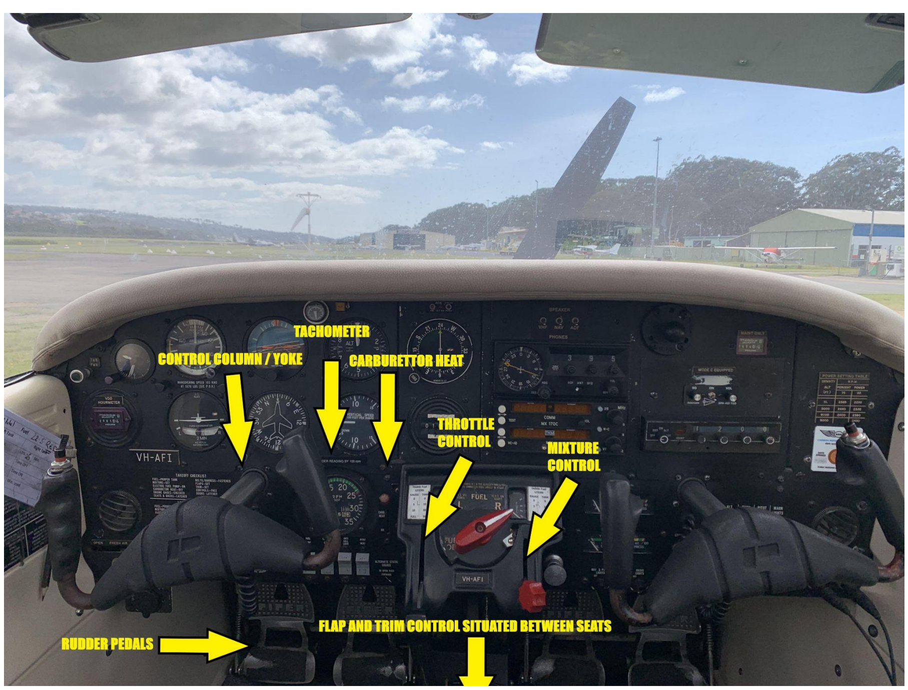
The mixture control is used by the pilot to alter the fuel/air ratio to the engine. Pushing the mixture forward gives a *rich* mixture (more fuel) and pulling the mixture back gives a *lean* mixture (less fuel).
Pulling the mixture control all the way back cuts the fuel supply and is how the pilot stops the engine at the end of a flight.
For RPL training the mixture control is typically kept in the "Full Rich" position, although your instructor will at some stage introduce the method of leaning the mixture for optimal fuel efficiency and performance.

Carburettor Heat:

Used to prevent and/or melt ice that can form in the carburettor. Carburettor icing is most likely to occur when operating for extended periods at low power settings, or in conditions of high relative humidity, and can significantly disrupt engine performance if not prevented or dealt with.



When air valve is in **hot** position, heated but unfiltered air flows into carburetor and filtered air is dumped overboard.

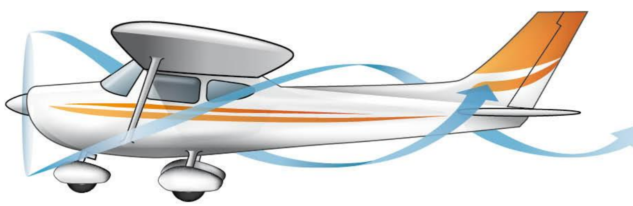


Considerations:

Effect of airspeed:
Control effectiveness increases as airspeed increases. It is similar to riding a bike at different speeds - if we go slow, we have to make big movements of the handlebar to get the bike where we want it; whereas, if we are going fast, the bike will change direction easily with a small movement of the handlebar.

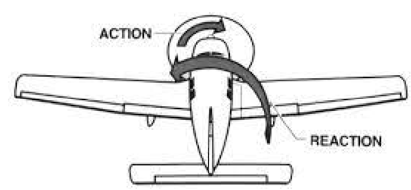
As an aircraft speeds up, any given amount of control deflection will generate an increasingly larger aerodynamic force, making the controls more effective.

Effect of slipstream:
Increased airflow due to propeller slipstream will increase rudder and elevator effectiveness but not aileron effectiveness. The aircraft will also develop a tendency to yaw to the left due to the increased airflow from the propeller hitting the vertical stabiliser.



Note: the PA38 Piper Tomahawk is an example of an aircraft with a T-Tail configuration, where the elevator sits higher than on a conventional tailplane. As a result, elevator control effectiveness benefits considerably less from the effect of slipstream than it would on an aircraft with a conventional tail - for example, the C172.

Effect of power:
An increase in power will cause the aircraft to pitch up and a decrease in power will cause the aircraft to pitch down. The reason for this pitching moment will be explored in the next lesson, Straight and Level.



Additionally, an increase in power will generate a ‘propeller-torque’ reaction (see right) that is most pronounced at low airspeed and high power settings. This induces a left-rolling/yawing tendency in flight.

And finally, an increase in power will also generate an increase in slipstream, the effect of which was discussed above.

Airmanship:

- Lookout
- Clock code (see AIRCRAFT BASICS brief)
- Ensure smooth but positive control movements
- Handover / Takeover Technique