STRAIGHT AND LEVEL - (Long Brief)

Aim:

To understand the basic aerodynamic principles and forces acting on the aircraft in Straight and Level flight at various airspeeds, power settings and attitudes.

Objectives:

By completion of this brief you will be able to recall and recite the four forces acting on the aircraft in Straight and Level flight and their relationship to each other. You will also be able to recall and recite the two main types of drag and the meaning of the terms equilibrium, stability and balance as they relate to this brief.

Revision:

Effects of controls

The aircraft axis

The concept of lift

Definition:

Straight & Level: Flight at a constant speed, altitude, heading, wings level and in balance.

Centre of pressure (CoP): The point on the aircraft at which lift acts through.

Centre of gravity (CoG): The point on the aircraft which weight acts through.

Attitude: The angle between the longitudinal axis of the aircraft and the horizon.

Application:

Used in navigation, travelling to and from the training area, and within the circuit.

Principles:

The Four Forces:

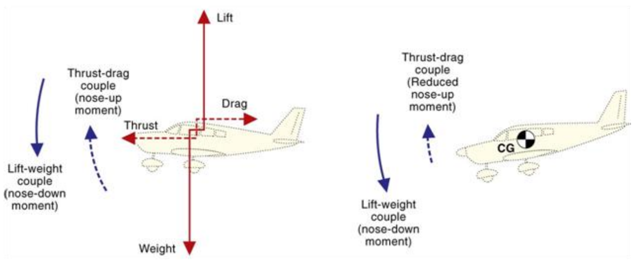
Recall the four forces acting on an aeroplane in flight: lift (L), weight (W), thrust (T) and drag (D).

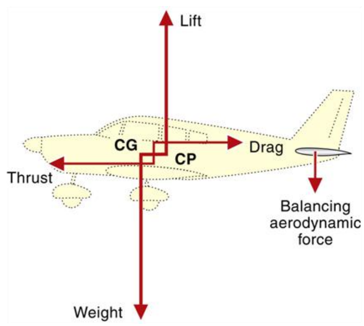
In straight and level flight, the aicraft is in *equilibrium*.

EQUILIBRIUM: No acceleration, deceleration or turning. In Straight & Level, this is T = D, L = W.

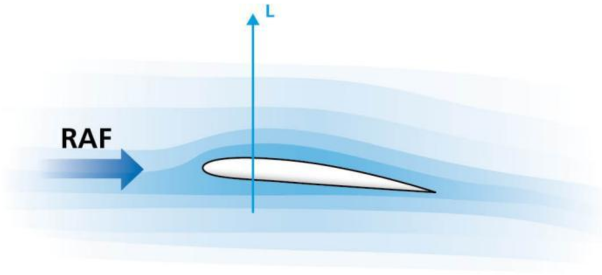
The positions of the lift force acting through the centre of pressure (CP) and weight force acting through the centre of gravity (CG) are not coincident - that is to say, they are offset and do not act at the one point. The CG is concentrated through the points of the aircraft that are heaviest - i.e. the engine, and therefore the CG is further forward than the CP. The outcome is that the opposing forces of lift and weight will set up a 'couple' causing a pitch moment. The same applies for the forces of thrust and drag.

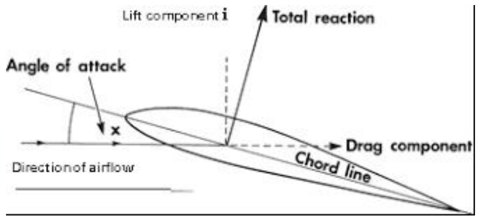
In straight and level flight, L and W creates a nose down pitching moment, while T and D creates a nose up pitching moment. Since the L and W moment is a much larger force than the T and D moment, the overall effect is a nose down pitching moment. This is balanced by the tailplane.





Lift:





Lift:

The lift force generated by an aerofoil can be found with the formula:

$$L = C_L \times \tfrac{1}{2}\rho\, v^2 s$$

1/2 = mathematical constant

ρ = 'rho', air density

V = aircraft's True Airpseed Speed (TAS)

CL = Co-efficient of lift. Combination of AoA and camber

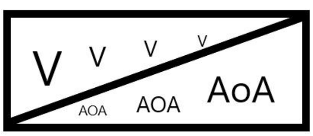
S = Surface area of aerofoil

The two pilot controlled factors relevant to straight and level are the aircraft's IAS (1/2 ρ V^2) and angle of attack (AoA).

- CL increases with an increase in AoA, or an increase in curvature while at constant AoA.
- For straight and level flight, LIFT must remain constant.
- For an increase in AoA (and therefore increasing CL), indicated airspeed (IAS) must decrease, and vice versa.
- If we reduce AoA, IAS must increase or lift will no longer equal weight.

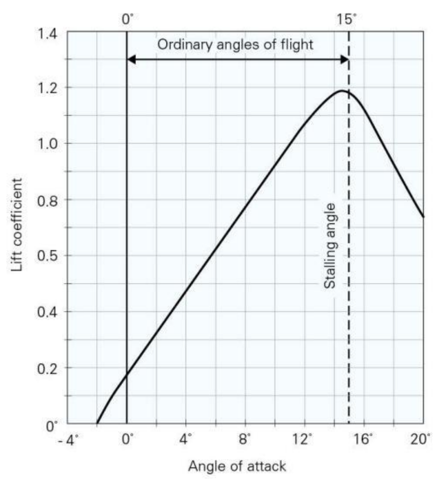
The pilot of a typical light general aviation aircraft has two primary means of modulating the amount of lift being produced. Air density is more or less fixed, as is the surface area of the wing, and the wing camber (assuming flap isn't used). What *can* be changed is the speed of the aircraft through the air and the AoA.

A simplified, more useful (to the pilot) Lift Formula is as follows:



Pilot's Lift Formula

Lift = AOA x IAS



Drag:

This is an aircraft's resistance to motion. If we can reduce Drag, we can reduce the amount of thrust required to balance it. There are two main types of drag, Induced Drag and Parasite Drag.

PARASITE DRAG:

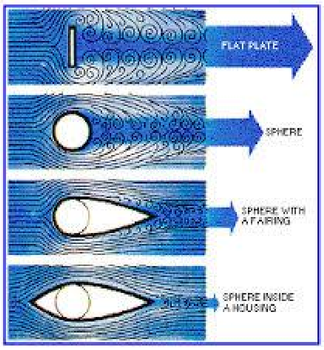
The three main types of drag that make up parasite drag are:

Skin friction drag: friction between the surface of an object and the air it moves through. It can be reduced by flush riveting, polishing etc.

Form drag: due to separation of airflow from the airframe to form turbulence. Reduced by streamlining, wheel spats, fairings.

Interference drag: due to interference at junctions (i.e. wing and fuselage). Reduced by fairings and streamlining.

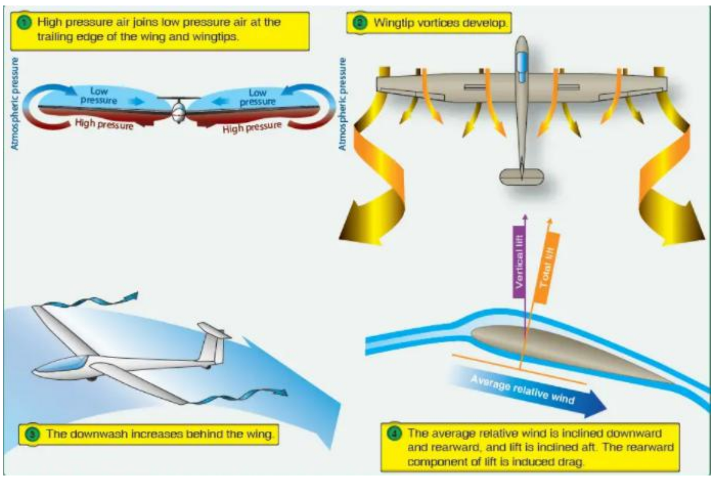
Form drag



It should be noted that **parasite drag INCREASES in direct proportion with airspeed**.

INDUCED DRAG:

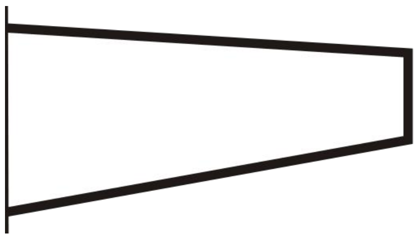
This type of drag is associated with the production of lift. Air spills from the relative high pressure area below the wing to the low pressure area above the wing. Vortices are formed (the largest ones at the wingtips) which deflect the air downwards, generating a drag force.



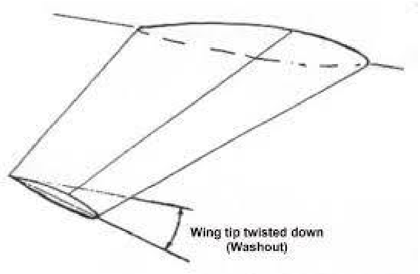
With an increase in AoA, the pressure gradient between the bottom and upper surface of the wing becomes larger, and so do the vortices. Therefore, if we are flying at a lower airspeed with high AoA, induced drag will be higher. **Induced drag DECREASES in direct proportion with airspeed.**

Induced drag can be reduced by:

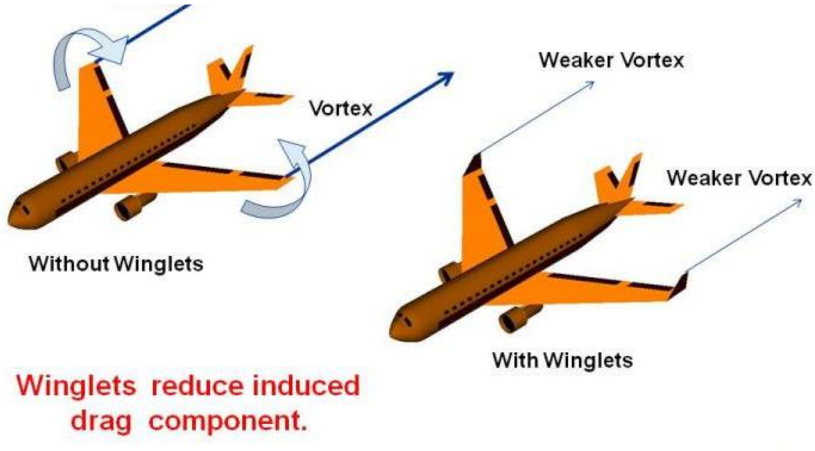
Tapered wings: a progressive decrease in the wing's surface area toward the wingtip, reduces the length of the chord line towards the tips, creating weaker wingtip vortices and less induced drag.



Washout: a progressive reduction in built-in AoA toward the wing tip. Since the wing tip is at a lower AoA than the wing root, the strength of the wing tip vortices is decreased.

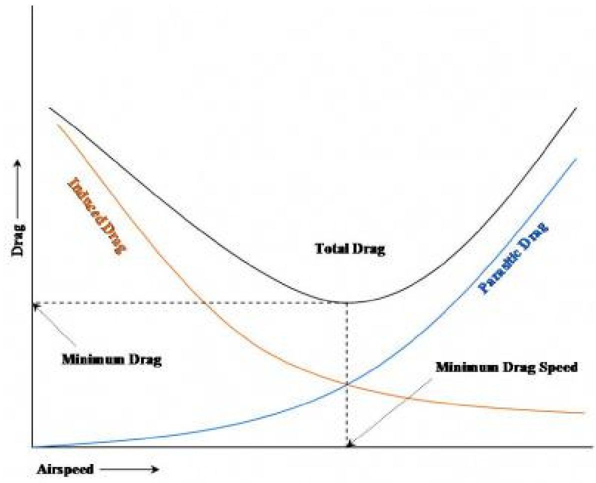


Modified wingtips: Wingtip design feature such as winglets redirect air at the tip of the wing to reduce the leakage of airflow around the wingtips and therefore the induced drag.



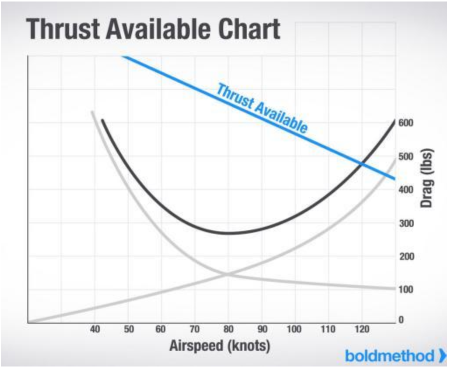
Total Drag:

Total drag is the sum of parasite drag and induced drag. You will notice that it is very high at both very low airspeeds and very high airspeeds, and is at a minimum somewhere in the middle. This is important for us to understand.



Thrust for straight and level flight:

Thrust is generated as a function of air being forced rearwards by the spinning propeller. In straight and level flight at a constant speed, Thrust = Drag. With a certain power setting, the aircraft will accelerate (or decelerate) until the amount of thrust being produced equals the total drag force. This occurs where the thrust available line intersects the (black) total drag curve. This corresponds to our maximum speed for a given amount of thrust.



Power + Attitude + Configuration = Performance

Recall the *Pilot's Lift Formula.*

Lift = AoA x IAS (angle of attack x indicated airspeed)

For straight and level flight, L=W. If our aircraft weights 1000kg, we must produce 1000kg of lift to continue flying level. Let's say a power setting of 1800 RPM gives us an airspeed of 60 knots while flying level, and it does this provided we maintain a high nose attitude which will equate to a high AoA.

We can say that in a no-flap configuration, a power setting of 1800 RPM + high nose attitude = 1000 kg Lift = Level flight

Let's now add power and increase our RPM to 2500 RPM. As the aircraft accelerates, we must lower our nose to prevent a climb. As we do so, the airspeed increases to 95 knots and we are flying with a lower nose attitude. We are still producing 1000kg of Lift, but we are now travelling faster, our nose is lower, and we now have a lower AofA.

We can say that in a no-flap configuration, a power setting of 2500 RPM + low nose attitude = 1000kg Lift = Level flight.

The higher our power setting and the faster we fly, the lower our nose attitude must be to fly level.

The lower our power setting and the slower we fly, the higher our nose attitude must be to fly level.

Therefore,

Power + Attitude (for a given configuration) = Performance

Considerations:

Balance:

Balance refers to whether or not the tail of the aircraft is aligned with the relative airflow during flight. If we are flying out of balance, then we will increase our drag on the aircraft and create an uncomfortable flight for any passengers we might have onboard. A balance ball is provided as part of the turn-coordinator instrument for us to monitor the aircraft's state of balance. The ball is free to move inside a fluid filled tube indicating that the aircraft is flying out of balance if the ball is not centred.

The pilot must apply left rudder when the ball is out to the left, and vice versa - this is known as "stepping on the ball".
See the diagram below of a turn co-ordinator and balance ball.

Stability:

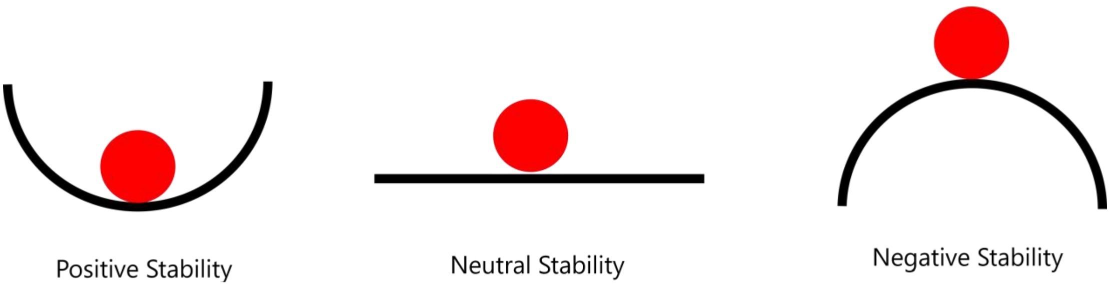
The natural tendency for the aircraft to return to its original flight path following a disturbance (ie. a gust of wind).

There are two main types of stability:

Static: the aircraft's in-built tendency to return to its original flight path.

Dynamic: The time or oscillations it takes to return to its original flight path.

There are threes degrees of stability:



Training aircraft are designed to be positively stable: they have an in-built tendency to regain straight and level when disturbed from their flight path.

Application:

- Maintaining a costant heading:

    External references

    - ✓ Instrument panel parallel to horizon
    - ✓ Nose pointing at a steady feature on horizon
    - ✓ Wingtips same distance from horizon (ie wings level)

    Internal references

    - ✓ Directional gyroscope and compass showing a constant heading
    - ✓ Artificial horizon indicating wings level

- Maintaining a constant height:
    - ✓ External - attitude constant
    - ✓ Internal - Altimeter constant, VSI reading zero

- Changing type of cruise: **P**OWER, **A**TTITUDE, **S**PEED, **T**RIM (P.A.S.T)
- Entry to cruise from a climb: **A**TTITUDE, **P**OWER, **S**PEED, **T**RIM (A.S.P.T)

Airmanship:

- Lookout
- Attitude
- Natural horizon is primary attitude reference, not the Attitude Indicator.
- Situational awareness.
- Smooth/gentle manipilation of the flight controls and throttle.