Lift is best explained by Newtonian mechanics.

Aircraft and wing design have stagnated for over 50 years due to the continued use of incorrect theories of lift (fluid mechanics).

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1 October 2022
Pre-Print DOI: 10.13140/RG.2.2.36518.86081;
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Keywords: Aerodynamics; airfoil; airplane; flight; lift; Newton; physics; wing.

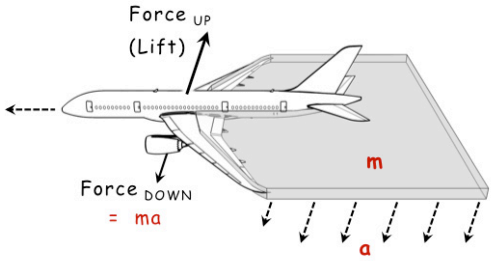

Fig. 1a Newtonian forces acting on an airplane.

Abstract

A re-evaluation of evidence indicates that Newtonian mechanics (Force = ma) based on absolute airflow analysis provides a more simple, straightforward and accurate explanation of how lift is generated than currently available. According to this novel Newtonian approach, wings with a positive AOA fly through a thin mass of air (m), which they accelerate (a) downwards, to create a downward force (Force $_{\text{DOWN}}$). The inertia of the air allows for a reactive equal and opposite upward force to be generated, which provides lift. See Fig. 1a. Taken a step further, Newtonian mechanics based on the mass flow rate (Lift = m/dt * dv) better explains active lift generation using absolute airflow analysis.

This Newtonian approach is significantly different to the existing explanations of lift based on fluid mechanics or the old Newtonian change in momentum (or flow turning) theories, which use relative airflow analysis.

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1. INTRODUCTION

A. *Wrong theory = Little progress.*

New technology has made airliners more efficient today with lighter materials and better engines. However, there has been little change in basic aircraft and wing design, or the approach to aeronautics, particularly since 1970.

The incorrect use of fluid dynamics and relative airflow analysis (i.e. wind tunnels) to explain the physics for how lift and drag are generated, has restricted progress in commercial passenger aviation. The stagnation is evident as airliners flying today are fundamentally the same designs and airspeeds as the B-747 that flew in 1969, over fifty years ago. See Fig. 1b.

Fig. 1b. Airliner designs in 1969 and 2010. [14]

B. *Significance of the Newtonian approach.*

The Newtonian approach offers to launch a new phase in technological progress in aviation. For example, it could permit the commercial adoption of new flying wing designs.

Analysis of the mass of air (m) flown through by the wings separately to the acceleration of this air (a) provides a better explanation for how lift (Lift = ma) is generated.

The Newtonian approach better explains how the lift generated by a wing is affected by: airfoil thickness, wing AOA, airspeed, aircraft momentum, aspect ratio, flight manoeuvers (e.g. inverted flight, …), and practical aspects of flight (e.g. ground effect, ….). In contrast, fluid mechanics (Navier-Stokes equations) cannot provide this level of detailed explanations.

This novel approach is extremely significant as lift is of fundamental importance to aviation. This paper is a synopsis of a more detailed analysis in “Newton explains Lift, Buoyancy explains Flight.” [2]

The theory of lift and the physics for how airplanes stay airborne remains unresolved and debated (see Appendix I). There is no accepted and conclusive experiment on a real aircraft in realistic conditions that proves any theory of how lift is generated to be correct. The Newtonian approach described above can be tested and verified, and therefore, offers to resolve the 100-year-old debate of how wings generate lift.

This paper explains the Newtonian approach in outline. A critique of existing theories of lift is beyond the scope of the paper. But for reference see: “Navier-Stokes fails to explain lift generation..” [3]

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Contents:

2. THE NEWTONIAN ARGUMENT SUMMARISED

(A one-page summary)

A. *Newtonian mechanics.*

Newtonian mechanics based on the mass flow rate is used to explain **active lift generation** using **absolute airflow analysis**. Simply put, the wings fly through a mass of air each second (m/dt), which is accelerated to a velocity downward (dv). This action creates a downward force. The inertia of the air allows for a reactive equal and opposite upward force, which provides lift; as this process is summarised by the equations: See Fig. 2a.

$$\text{Force}_{\text{DOWN}} = ma = m/dt * dv = \text{Force}_{\text{UP}} \text{ (Lift)}$$

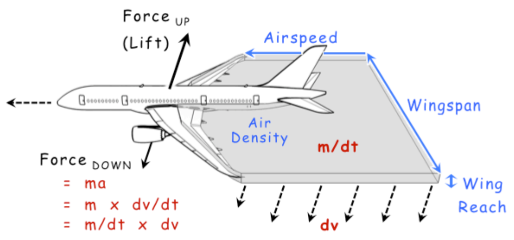


Fig. 2a. Newtonian forces acting on an airplane.

B. *Passive vs. Active lift generation*

Wings can create forces in two ways: (1) passively re-direct a relative airflow (headwind); or (2) actively displace the thin slice of static air flown through downwards and slightly forward. See Fig. 2b-i.

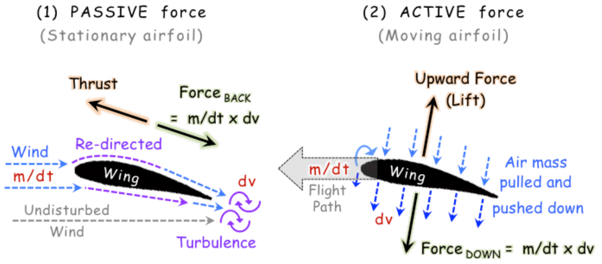


Fig. 2b-i. Active and passive force creation.

This paper argues that the wing airflows and resultant forces observed in practice, are not accurately depicted using relative airflow diagrams used by fluid mechanics. But wing airflows are more accurately depicted by absolute airflow analysis and Newtonian mechanics. See Fig. 2b-ii.

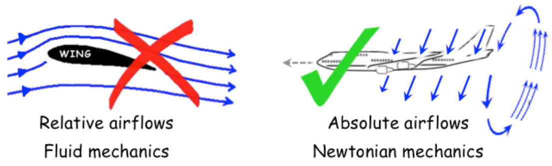


Fig. 2b-ii Relative and absolute wing airflow diagrams.

C. *New analysis.*

The Newtonian approach allows lift (Lift = m/dt * dv) to be analysed separately between the mass of air flown through by the wings each second (m/dt) and the velocity (dv) to which this air is accelerated. No one has done this previously.

This new approach better explains how lift is generated, as well as providing solutions to long-standing aeronautical enigmas and paradoxes. Analysis of 'm/dt' and 'dv' separately also provides novel and useful insights, including:

- How wingspan and wing depth (chord) affect lift.
- How engine thrust and induced drag affect lift.
- How 2D and 3D lift distribution varies across a wing.

D. *Newton applied to explain lift.*

The Newtonian approach allows for a better explanation of all aspects of lift generation, including:

- Stalls and flight manoeuvers; including:

  Cruise flight, flaps, slow flight, take-off, final approach, landing, descent, inverted flight, banking, adverse yaw, …
- Practical aspects of lift; including:

  Engine positions, gliding, anhedral vs. dihedral wings, winglets, Prandtl flying wing, canards, variable sweep wings, biplanes, airfoils generate only lift, airfoil thickness, delta wins, ground effect, supersonic flight, ….
- How aircraft momentum and the kinetic energy used to generate lift can be assessed.
- The Newtonian approach can be applied to explain the standard equations lift and drag for an airplane in flight:

$$\text{Lift} = 0.5\,(\text{Aircraft Velocity}^2 * \text{Air Density} * \text{Wing Area} * \text{Coefficient of Lift})$$

$$\text{Drag} = 0.5\,(\text{Aircraft Velocity}^2 * \text{Air Density} * \text{Surface Area} * \text{Coefficient of Drag})$$

E. Summary.

Newtonian mechanics provides a better and more comprehensive description of all aspects of lift generation than currently exists. This paper is extremely significant as it is the first time the Newtonian approach based on the mass flow rate has been presented in any detail to explain how lift is generated by a wing.

3. ACTIVE AND PASSIVE FORCES

A. Relative vs. Absolute airflow analysis.

Wing airflow diagrams are critical as they provide the basic model to analyse how wing airflows generate forces such as thrust or lift. Relative and absolute wing airflow diagrams show the same airflow in very different ways. See Fig. 3a.

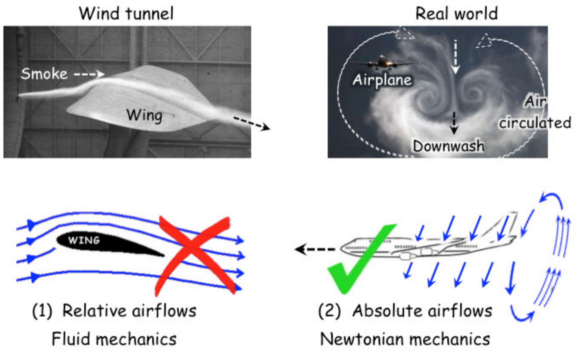


Fig. 3a. Relative and absolute airflows.

These two different wing airflow diagrams are compared:

1) **Relative wing airflow diagrams** have been used for the last hundred years as the basic template by fluid mechanics to analyse how wings interact with airflow to generate forces like lift. For example, relative wing airflow diagrams accurately reflect how moving air interacts with a stationary wing in wind tunnels.

   However, wingtip vortices and the circulation of the air behind the aircraft are notably absent from the relative wing airflow diagrams and any passive force generation (i.e. thrust or lift generation) by a wing in practice.

   According to Newtonian mechanics, relative wing airflow diagrams are an example of passive force creation. It is wrong and inaccurate to use relative wing airflow diagrams to analyse how a wing actively generates lift.

2) **Absolute wing airflow diagrams** show the airflows created by a wing of an aircraft moving through stationary air. The wings push air directly downwards to create downwash, which is circulated upwards on either side of the wings around the two wing-tip (wake) vortices. These airflows can be used to depict how a wing actively generates a force according to Newtonian mechanics.

Summary

The analysis above demonstrates that the prevailing method employed by fluid mechanics to analyse how an airplane wing actively generates lift using relative wing airflow analysis is wrong, inaccurate, and misleading. In contrast, absolute airflow analysis based on Newtonian mechanics provides an accurate method to assess the lift actively generated by a wing.

B. Passive vs. Active lift generation.

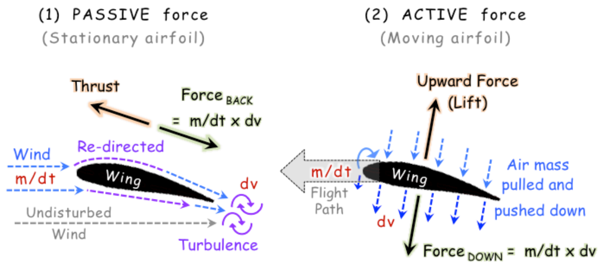


Fig. 3b-i. Passive and active creation of forces.

Stationary and moving airfoils generate different airflows, and therefore, different forces. The same airfoil (e.g. wing, propeller blade, or sail) can passively or actively create airflows and forces; calculated using Newtonian mechanics based on the mass flow rate (Force = m/dt * dv). See Fig. 3b-i.

1) An oncoming relative airflow (headwind) can be **passively** re-directed by a stationary airfoil. The mass of air re-directed each second (m/dt) decelerates (dv) on contact with the undisturbed wind, at the trailing edge of the airfoil. This process produces turbulence and creates a backward force (Force $_{BACK}$ = m/dt * dv). The inertia of the air provides resistance, allowing for a reactive equal and opposite forward force (thrust) to be generated.

2) A moving airfoil can **actively** accelerate a mass of static air each second (m/dt) to a velocity (dv) downward and slightly forwards, creating a downward force (Force $_{DOWN}$ = m/dt * dv). The inertia of the static air allows for reactive equal and opposite upward force to be generated.

The key differences between passive and active forces include:

- The **reaction to passive forces** arises due to the change in **inertia** from the decrease in velocity of the relative airflow (wind) at the trailing edge of the airfoil, which produces turbulence. In contrast, the **reaction to active forces** arises from the **inertia** of the static air accelerated by the airfoil.
- **The direction of the force generated** by active force is almost perpendicular to the alignment of the airfoil, but for passive forces, it is close to the alignment of the airfoil.
- **Passively** generated forces produce **wake turbulence**, with no air being circulated and **no vortices**. In contrast, **actively** generated forces produce spirals of streamlined **laminar wake airflow,** which circulates around the two turbulent wingtip vortices. See Fig. 3b-ii.

Fig. 3b-ii. Turbulent vs. smooth wake airflows.

4. NEWTON EXPLAINS LIFT

*A. Lift = m/dt * dv*

Newtons Laws of Motion describe the relationship between the motion of an object (airplane) and the forces acting on it can be applied in three ways to explain the lift generated by a wing: See Fig. 4a-i.

1) Simple explanation: Lift = ma
2) Momentum theory: Lift = ma = d(mv)/dt
3) Mass flow rate : Lift = ma = m/dt * dv

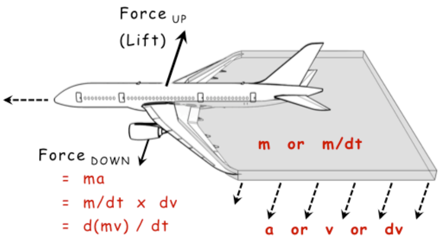


Fig. 4a-i Newtonian forces acting on a wing shown by three equations.

These three methods of explaining lift are described below. All equations are based on Newtons 2nd Law of Motion (Force = ma). All equations are correct, complimentary, and produce the same values for lift through different perspectives.

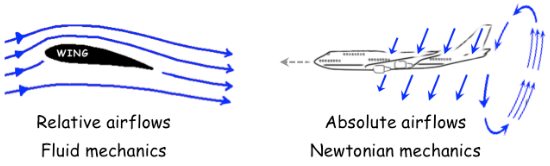
Other equations:

- Kinetic Energy = K.E. = $0.5\ mv^2$ [1]
- Momentum = mv [1]

Definitions:

- m = Mass of air the wings fly through.
- m/dt = Mass per unit time. The mass flow rate.
- dt = Change in time (i.e. per second).
- dv and v = Change in velocity of the air; and the velocity that the air flown through is accelerated to in one second (downwash velocity). i.e. ‘dv = v’.
- a = dv/dt (acceleration).

The **wing airflow diagrams** and analysis used by the Newtonian approach depict a moving wing passing through static air; i.e. Absolute wing airflows. In contrast, the relative airflow analysis used by fluid mechanics (Navier-Stokes equations) and the flow-turning theories for lift depict the wing as stationary with relative airflows moving around the wing. See Fig. 4a-ii.



Relative airflows
Fluid mechanics

Absolute airflows
Newtonian mechanics

Fig. 4a-ii. Relative and absolute airflow diagrams.

B. Three Newtonian equations for lift.

(1) The simple Newtonian explanation (Lift = ma)

According to Newtonian mechanics, wings with a positive angle-of-attack (AOA) fly through a mass of air (m) in flight. This thin slice of air is accelerated (a) downwards to create a downward force ($\text{Force}_{\text{DOWN}} = ma$). The reactive equal and opposite upward force generated (Force_{UP}) provides lift; as summarised by the equations: See Fig. 4b-i.

$\text{Force}_{\text{DOWN}} = ma = \text{Force}_{\text{UP}}$ (Lift)

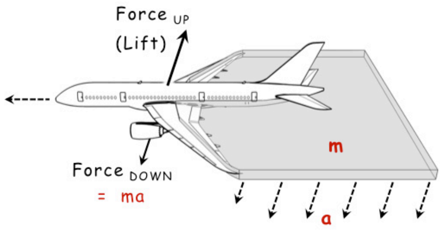


Fig. 4b-i Newtonian forces acting on a wing.

(2) Momentum theory: Lift = d(mv)/dt

There is no net gain or loss of momentum, energy and mass in the process of generating lift. In flight, wings transfer momentum and kinetic energy from the aircraft to the air, by accelerating the air flown through downwards to a velocity (v) to generate lift, which can be expressed by the equations: See Fig. 4b-ii.

$Force_{DOWN} = ma = m * dv/dt = d(mv)/dt$ [1]

$K.E. = 0.5\ mv^2$ [1]

The momentum and kinetic energy used to generate lift are calculated using the same factors; ‘m’ and ‘v’.

The downward force generates a reactive equal and opposite upward force, which provides lift. Combining the equations above allows lift to be expressed as the change in momentum of the air accelerated downwards:

$Force_{DOWN} = Force_{UP}$ *(Lift)* $= d(mv)/dt$

Or simply: *Lift* $= d(mv)/dt$

Units: $N = (kg\ m/s)/s$

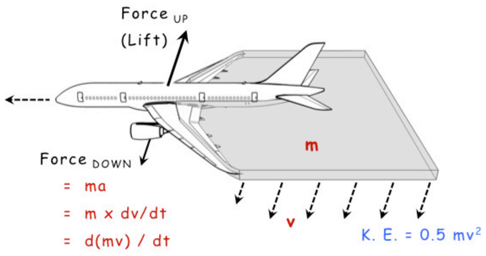


Fig. 4b-ii. Lift generated by transferring momentum and K.E. to the air.

(3) The mass flow rate: Lift = m/dt * dv

Newtonian mechanics based on the mass flow rate is used to explain **active lift generation** using **absolute airflow analysis**. Simply put, the wings fly through a thin layer of air that is accelerated downward. The reactive equal and opposite force pushes the wings and aircraft upward. See Fig. 4b-iii.

For an airplane in stable flight through static air, wings with a positive angle-of-attack (AOA) fly through a mass of air each second (m/dt), which is accelerated to a velocity (dv) downward. This action creates downwash and a downward force (Force $_{DOWN}$), as summarised by the equation:

$$Force_{DOWN} = ma = m * dv/dt = m/dt * dv \quad [1]$$

The inertia of the air provides resistance to the downward force, producing a reactive equal and opposite upward force (Force $_{UP}$) that provides lift, as shown by the equation:

$$Force_{DOWN} = Force_{UP}\ (Lift)$$

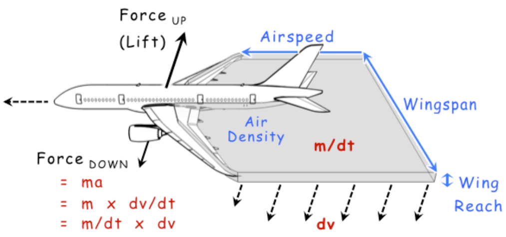


Fig. 4b-iii. Newtonian forces acting on an airplane.

Lift is defined as the vertical component of the upward force, in the opposite direction to gravity. Lift is just the vector in the vertical direction. See Fig. 4b-iv.

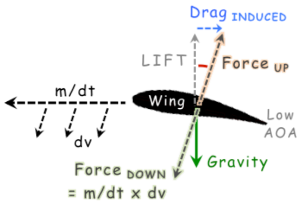


Fig. 4b-iv. Forces acting on a wing.

For simplicity, it is assumed that an airplane in flight at a very low wing AOA, the upward force is close to the vertical direction. Therefore, induced drag is negligible, and lift equals the upward force, as shown by the equation:

$$Force_{UP} = Lift$$

The equations above for the momentum transferred from the wings to the air (i.e. the change in momentum of the air) are combined as follows:

$$\begin{array}{llll} Force_{DOWN} = Force_{UP}\ (Lift) & = & m/dt & * \ dv \\ Simplified\ to: \quad Lift & = & m/dt & * \ dv \\ Units: \quad N & = & kg/s & * \ m/s \end{array}$$

The Newtonian approach based on the mass flow rate is a different approach to the old Newtonian explanations of lift based on a change in momentum or flow turning.

Mass flow rate (m/dt)

'm/dt' is a product of the volume of air flown through each second by the wings and air density. The volume of air flown through depends on airspeed, wingspan, and wing reach (i.e. wing AOA and wing thickness). 'm/dt' is also the downwash created by the wings.

'm/dt' increases with airspeed. Therefore, lift is expressed as the mass flow rate 'm/dt', and not 'm', because this factor of lift is time-dependent. i.e. Lift depends on the amount of air flown through by the wings each second.

Downwash velocity (dv)

'dv' depends primarily on aircraft momentum (airspeed and mass), wing AOA, and wing depth (chord). Slower and lighter aircraft have less momentum. Their wings strike each air molecule in their path with less force, which accelerates the air to a lower velocity (lower dv).

'dv' is caused by a one-off force (impulse) from the wings, which accelerates the air. Therefore, 'dv' is not time-dependent; and not expressed as acceleration 'dv/dt'. 'dv' does not change if the time period is altered.

Evidence of downwash

A wing can only generate lift if it accelerates a mass of air downward, which creates downwash and a pressure impulse as observed behind airplanes. The evidence is more evident from heavier and faster aircraft, which need to accelerate air down aggressively in order to generate the significant lift needed to fly. See Fig. 4b-(iii-v).

Fig. 4b-iii. Downwash evident behind airplanes.

Fig. 4b-iv. A-380 flying through clouds. [46]

Fig. 4b-v. Pressure impulse below jets. [23]

C. *Additional considerations.*

Newtons Laws of Motion

Strictly, Newtons 2^{nd} Law of Motion does not specifically state that force equals mass times acceleration (Force = ma). “Newton’s second law …. states that the time rate of change of the momentum of a body is equal in both magnitude and direction to the force imposed on it. The momentum of a body is equal to the product of its mass and its velocity.” [39]

Therefore, the equation describes force as a product of the mass flow rate and its velocity (Force = m/dt * dv), which is a generally accepted derivation of Newtons 2^{nd} Law. [1]

This difference may have arisen because the mass of the object was assumed to be fixed by Newton and others. Only later the equation was adjusted to account for how the mass flow rate exerts a force. Consequently, the Newtonian equation for the mass flow rate could also be written using ‘dm/dt’; as summarised by the equation:

$$Force_{DOWN} = ma = dm * dv/dt = dm/dt * dv$$

However, in this paper for simplicity the terminology ‘m/dt’ is used, rather than ‘dm/dt’, because in most situations the mass flow rate is only time dependent. The surface area facing the direction of travel (flight) is constant. i.e. The wingspan and wing reach is fixed, while airspeed varies.

Therefore, it is easier and less confusing to express the lift generated as a function of 'm/dt', rather than as 'dm/dt'. However, this issue is only a presentation consideration, the physics associated with the terms 'm/dt' and 'dm/dt' is the same.

Supplementary information:

- Fluid viscosity is not significant to the forces applied by the wings to the air. Viscosity is only important to the behaviour of the air once accelerated by the wings, and therefore largely irrelevant to the calculation of lift.
- This analysis of lift is only related to the wings. It does not include the potential effects on lift from the tail and horizontal stabilizers, or the fuselage for simplicity.
- The lift required to fly depends on the aircraft’s mass, which is pushed upward against gravity.
- The faster and heavier aircraft have greater momentum available to be transferred to the air to generate lift.
- In the lift generation process, ‘dv’ acts like an accelerator pedal for the mass of air flown through (m/dt).
- Newtonian mechanics can be used to explain the forces created by airplane wings, propellers, jet engines, and rotors, which have similar shapes, designs and functions.
- A transfer of momentum from the aircraft to the air to generate lift causes the aircraft’s velocity (v) to decline, as the aircraft’s mass (m) is constant.
- The kinetic energy required to generate lift is proportional to the velocity of the downwash squared (K.E. = 0.5 mv^2).

D. *Old Newtonian theories of lift.*

Applying Newtonian mechanics to explain lift is not a new concept. But applying Newtonian mechanics based on the mass flow rate in detail and depth is innovative. In addition, using absolute airflows and a focus on the circulation of the air behind the aircraft to explain lift is entirely unprecedented.

The old Newtonian ‘momentum’ and ‘flow turning’ theories of lift asserted that wings re-direct relative airflow downwards, which transfers momentum from the aircraft to the air. The equal and opposite force pushes the aircraft up. [1]

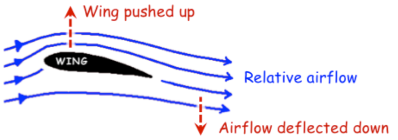


Fig. 4d-ii. Wing airflow diagram – momentum theory.

NASA’s website states that both Bernoulli (fluid mechanics) and Newton (momentum theory) provide correct explanations for lift. [1] However, NASA’s approach is impossible and illogical, as these are two incompatible and non-complementary theories. Also, NASA fails to specify what proportion of lift is explained by fluid mechanics and what proposition is explained by Newtonian mechanics; 50% / 50% or 70% / 30% ? No attempt is made to combine the equations from Newtonian and fluid mechanics, to provide one equation for lift.

The book ‘Understanding Flight’ [5] uses Newtonian mechanics to explain lift. It states: “In the simplest form, lift is generated by the wing diverting air down, creating the downwash.” The author also stated: “We did the calculation for a 250 ton airplane at 35,000 feet, and it is diverting (downwards) its own weight per second to keep in the air.” [40]

The book: “Stick and Rudder” by Wolfgang Langeweische (1944) [4], in Chapter 1 states: “ The wing keeps the plane up by pushing air down. …. In exerting a downward force on the air, the wing receives an upward counterforce – by the same principle, known as Newton’s law of action and reaction, …. ” See Fig. 4d-i.

Fig. 4d-i. Books: ‘Understanding Flight’ & ‘Stick and Rudder.’

A paper “A comparison of explanations of aerodynamical lifting force” (1987) [13] calculated lift using Newtons 2^{nd} Law, based on the change in momentum of the air and the mass flow rate of the air pushed downwards by the wing; using the equation: Force = d(mV)/dt = dm/dt * V ; where: V = Velocity of the airstream. However, the approach above relies on relative airflow analysis, not absolute airflow analysis.

E. *Analysis of lift generation is complex.*

Analysis of how lift generation changes with the different variables such as airspeed and wing AOA is complex. -The extent to which a change in one factor can affect lift varies a lot, depending on the starting and ending aircraft configuration, and how factors are inter-related.

- Many key variables (e.g. airspeed, momentum, aspect ratios, flaps, wing AOA, ….) **can affect both 'm/dt' and 'dv' factors in a linear and non-linear manner**.
- Changes in factors can cause a significant or a minor change in lift **depending on the initial aircraft configuration and the initial mix of how lift is generated from 'm/dt' and 'dv'.**
- Many **factors are inter-dependent**. A change in one variable can affect 'm/dt' and 'dv', and therefore lift.

  Changes in 'm/dt' and 'dv' can then have a **secondary effect** on how other factors affect 'm/dt' and 'dv', and therefore lift. The secondary changes can be in positive or negative direction; potentially leading to **positive or negative feedback loops**.

For example, for an airplane in stable flight, a small change in wing AOA can cause:

- A significant change in the Coanda effect and 'm/dt' generated by the topside of the wing. In turn, this change causes the lift generated (Lift = m/dt * dv) to change dramatically.

  However, this is not always the case. A small change in wing AOA can cause only a small change in the Coanda effect, depending on the circumstances.
- An increase in wing reach, which then increases 'm/dt', and therefore, increases lift.
- Assuming no change in engine thrust (throttle), the higher wing AOA causes an increase in induced drag, which then causes a reduction in airspeed and aircraft momentum. These changes have a secondary effect of reducing 'm/dt' and 'dv', and therefore reducing lift, which limits the primary effects of increased lift.

This complexity of lift generation means that during flight manoeuvers pilots maintain lift by altering different aircraft controls simultaneously. Rather than just changing one control at a time. For example, to increase airspeed and maintain altitude in cruise flight. A pilot can increase engine thrust and reduce the wing AOA simultaneously. Only increasing engine thrust and not altering the wing AOA would cause the airplane to gain altitude.

Significance

Lift analysis is complex. However, Newtonian mechanics significantly improves the methods available to analyse lift. In turn, this dynamic permits improved explanations of how the different variables (e.g. airspeed, momentum, aspect ratios, flaps, wing AOA, ….) affect lift, by allowing for the analysis of the components parts 'm/dt' and 'dv' separately.

F. *'m/dt' and 'dv' analysed separately.*

A benefit of the Newtonian approach is that 'm/dt' and 'dv' can be analysed separately to understand better how lift is generated. Different factors affect 'm/dt' and 'dv' differently and 'm/dt' and 'dv' can be displayed graphically. See Fig. 4f-(i-ii).

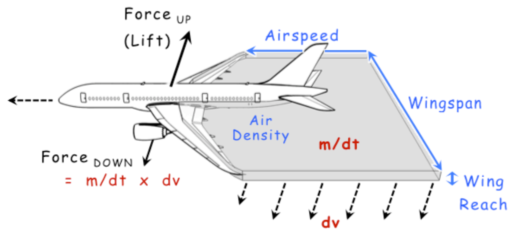


Fig. 4f-i. Newtonian forces acting on an airplane; showing 'm/dt' and 'dv' analysed separately.

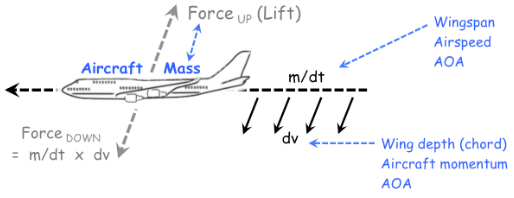


Fig. 4f-ii. 'm/dt' and 'dv' analysed separately.

The Newtonian approach allows for the lift generated by different aircraft configurations, wing shapes, flight conditions, etc….. to be compared and analysed in new ways. In addition, the alternative methods of generating lift between 'm/dt' and 'dv' can be presented graphically, along a constant lift curve. See Fig. 4f-iii.

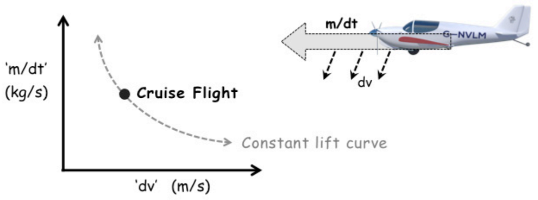


Fig. 4f-iii. Graph comparing 'm/dt' and 'dv', for constant lift.

The terminology used in this paper includes:

Low / high 'm/dt' or 'dv' = Low / high lift generated from the mass of air flown through (m/d), or the downwash velocity (dv), as compared to a benchmark (e.g. cruise flight).

G. Example – high-speed and slow flight compared.

Cruise, high-speed and slow flight are compared for a propeller airplane. This comparison illustrates the benefits and insights gained from analysing how lift is generated (Lift = m/dt * dv), from 'm/dt' and 'dv' separately. The different configurations are shown graphically along a constant lift curve in Fig. 4g-i.

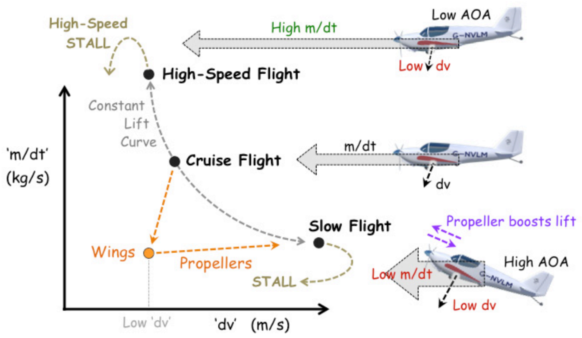


Fig. 4g-i. Lift composition – 'm/dt' and 'dv compared.

According to Newtonian mechanics:

- **Cruise flight** is used as the base or benchmark to compare the other flight configurations. The airplane adopts a low wing AOA and flies through a mass of air each second (m/dt), which is accelerated downwards to a velocity (dv). This action generates lift as summarised by the equation:

  $\text{Lift}_{\text{WINGS}} = m/dt \; * \; dv$

  It is assumed that the propellers contribute a negligible amount to lift as the wings have a low AOA. Therefore, the propellers are aligned horizontally.

- **In high-speed flight** the airplane adopts a very low wing AOA and a flat aircraft configuration. The airplane flies through a high mass of air each second (high m/dt) due to the high airspeed, despite the lower wing reach from a low AOA.

  As a consequence of the high 'm/dt', the air flown through only needs to be accelerated downwards to a low velocity (low dv) in order to generate enough lift to fly. This dynamic is summarised by the equation:

  $\text{Lift}_{\text{WINGS}} = \text{high 'm/dt'} \; * \; \text{low 'dv'}$

  The increased aircraft momentum is of little benefit.

  At a low wing AOA in horizontal flight, if the propellers are aligned horizontally they contribute a negligible amount to lift, and only push the airplane forwards.

- **In low-speed horizontal flight** (slow flight), with its nose raised to provide a high wing AOA. The wings fly through a small mass of air each second (low m/dt) due to the low airspeed, despite the increased wing reach.

  Slower aircraft have less momentum, and their wings strike each air molecule with less force. Consequently, slower aircraft produce lower downwash velocity (lower dv).

  In addition, the downwash is accelerated down at a less vertical angle as compared to cruise flight. This dynamic increases induced drag, and reduces the lift generated by accelerating the air downwards (lower dv).

  The lift generated by the wings is lower than in cruise flight and can be summarised by the equation:

  $\text{Lift}_{\text{WINGS}} = (\text{low } m/dt \; * \; \text{low } dv)_{\text{WINGS}}$

  Also, in slow flight the lift is generated over a short distance, due to the low airspeed. This is evident from the 3D image of lift generation. See Fig. 4g-ii.

  The propellers' primary task is to push the airplane forwards through the air. But propellers can also boost the total lift generated if pointed downwards, by accelerating a very small mass of air each second (low m/dt) to a very high velocity (high dv), as summarised by the equation:

  $\text{Lift}_{\text{PROPELLERS}} = (\text{low } m/dt \; * \; \text{high } dv)_{\text{PROPELLERS}}$

  Total lift generated in slow flight by the wings and propellers can be combined, as shown by the equations:

  $\text{Lift}_{\text{TOTAL}} = \text{Lift}_{\text{WINGS}} + \text{Lift}_{\text{PROPELLERS}}$

  $\text{Lift}_{\text{TOTAL}} = (\text{low } m/dt \; * \; \text{low } dv)_{\text{WINGS}} + (\text{low } m/dt \; * \; \text{high } dv)_{\text{PROPELLERS}}$

  $\text{Lift}_{\text{TOTAL}} = \text{low } m/dt \; * \; \text{high } dv$

- Including the lift generated by the propellers and wings, the total lift generated is the same for the different configurations (cruise, high-speed and slow flight).

These are only examples of how high-speed and slow flight can be achieved. Alternative combinations of 'm/dt', 'dv', and the propeller thrust exist to produce the same total amount of lift needed to fly.

3D lift distributions

The differences in lift distribution across wings and the horizontal distance flown by the aircraft, highlights differences in how lift is generated between high-speed and slow flight. The example of a small airplane with rectangular wings is used for this illustration. As compared to slow flight, in high-speed flight the lift generated is spread out over a longer horizontal distance due to the airplane's higher airspeed. See Fig. 4g-ii.

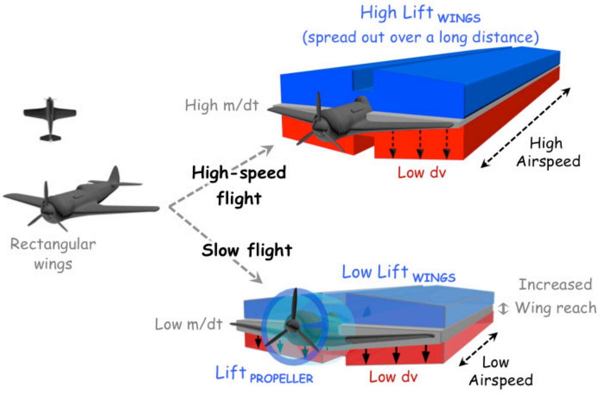


Fig. 4g-ii. 3D lift distribution of a small airplane with rectangular shaped wings, in high-speed flight.

H. Lift distribution: Glider vs. Harrier.

Newtonian mechanics is used to illustrate lift distribution across different wings. In this example, a slow and light glider is compared to a fast and heavy Harrier (fighter jet), as they have significantly different aspect ratios and aircraft momentum.

It is assumed that:

- The glider's wingspan is about 3 times longer than the Harrier's wingspan. More precisely, in this example the glider has a 30 meter wingspan, which is about 3.2 times greater than the Harrier's 9.4 meter wingspan.
- The glider flies at about one-third (1/3rd) the airspeed, as compared to the Harrier.
- The glider has thinner wings (smaller chord), but the same wing area as compared to the Harrier.
- The glider and Harrier have the same wing reach.

Consequently, the data above used in this example means that the absolute mass of air flown through each second (m/dt) is the same for the glider and Harrier, which is a 'modest m/dt'.

- It is significant that the mass of air flown through each second (m/dt) by a fast jet can be comparable to the m/dt of a slow glider.
- Even though 'm/dt' is the same for both aircraft in absolute amounts (in this example), the total lift generated is very different due to different values for downwash velocity (dv). This dynamic provides a significant insight into how lift is generated.

Glider

A glider's long wingspan (high aspect ratio wings) flies through a large mass of air each meter (mass / meter). But its slow air speed means that it manages to fly through only a relatively modest mass of air each second (modest m/dt). This air is accelerated downward at a low velocity (low dv) due to the aircraft's limited momentum. Overall the glider generates a small amount of lift required to fly. This dynamic is summarised by the equation:

Modest m/dt = long wingspan * low airspeed

Low LIFT = modest 'm/dt' * low 'dv'

Harrier (fighter jet)

The Harrier's short wingspan (low aspect ratio wings) fly through a small mass of air each meter flown (low 'm'). However, the Harrier's high airspeed means that it manages to fly through a relatively modest mass of air each second (modest m/dt), despite the short wingspan. This dynamic is summarised by the equations:

Modest m/dt = short wingspan * high airspeed

Modest m/dt = low ('m' / meter) * high (meter / second)

This air flown through each second (modest m/dt) is accelerated downward at a high velocity due to the Harrier's significant momentum (high dv). Overall, the much heavier Harrier generates a significantly greater amount of lift required to fly, as compared to the lighter glider. This dynamic is summarised by the equation:

High LIFT = modest m/dt * high dv

In this example, the glider and Harrier wings fly through the same mass of air each second (modest m/dt). The key difference in lift profile between the glider and the Harrier is primarily due to differences in the velocity of the downwash (dv). See Fig. 4h-(i-ii).

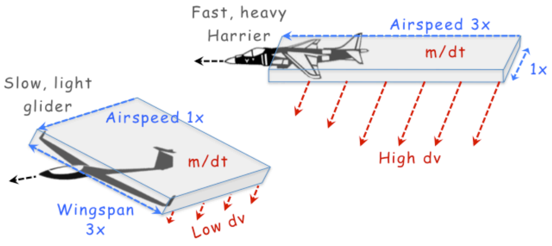


Fig. 4h-i. 3D lift generation
for a glider and Harrier compared.

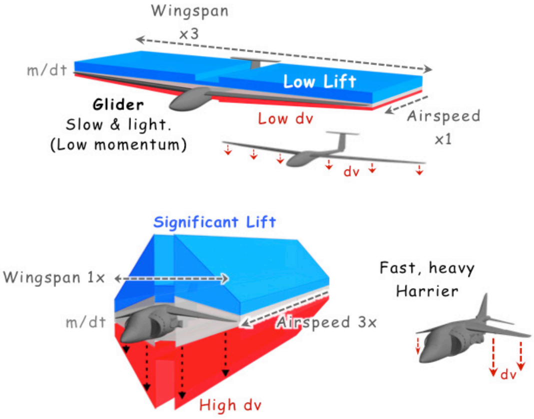


Fig. 4h-ii. 3D lift distribution
for a glider and Harrier compared.

The Harrier's 3D lift distribution above is spread out over a long horizontal distance due to the Harrier's high airspeed.

For simplicity, the 3D lift distribution above only shows the underside of the wing accelerating air downwards to create downwash. In practice, the topside and underside of the wings accelerate air downward.

The differences between how a glider and harrier generate lift in the example above, can be shown graphically by two separate constant lift curves. See Fig. 4h-iii.

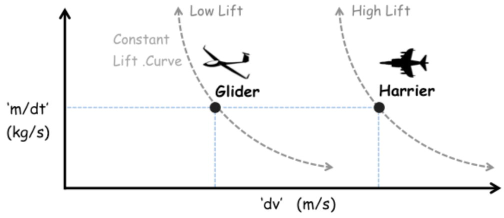


Fig. 4h-iii. Constant lift curves compared.

I. Paper airplanes.

The same Newtonian mechanics that explains how conventional airplanes generate lift to fly, can also be used to explain how paper airplanes fly.

The wings of a paper airplane with a positive AOA fly through a mass of air each second (m/dt) that they accelerate downwards to a velocity (dv). This action creates a downward force ($\text{Force}_{\text{DOWN}}$). The inertia of the air allows for a reactive equal and opposite upward force to be generated, which provides lift. This process can be described by the equations: See Fig. 4i-(i-ii).

$$\text{Force}_{\text{DOWN}} = m/dt * dv = \text{Force}_{\text{UP}} \text{ (Lift)}$$

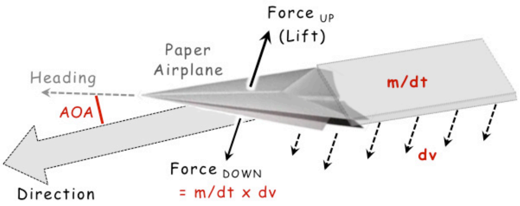


Fig. 4i-i. Newtonian forces acting on a paper airplane.

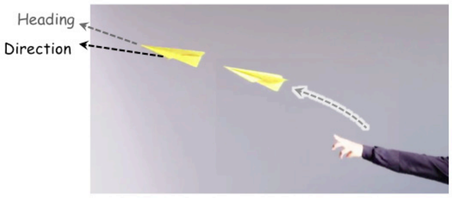


Fig. 4i-ii. Paper airplane trajectory. [38]

Paper airplanes are noteworthy due to their ability to fly and glide despite their straight wings. Key differences between a conventional airplane and a paper airplane include:

- Paper airplanes typically lack structural stiffness, and therefore, cannot withstand large forces.
- Paper airplanes typically lack mass, and therefore, lack momentum that can be transferred to the air to generate lift. The forces involved in a paper airplane generating lift are relatively small.
- Paper airplane lacks an engine, and therefore, must glide and cannot sustain flight for long.
- The paper airplane design (ailerons, elevators, ….) can be altered to adjust the airflows produced, and therefore, the direction and size of the forces generated.
- Conventional paper airplanes have a delta wing design, which can benefit lift from Leading Edge Vortices (LEVs) on the topside of the wings.
- Paper airplane wings are typically straight and lack wing curvature. In turn, this aspect indicates a minimal Coanda effect and restricted ability of the topside of the wing to pull air above it downwards.

  This dynamic explains why paper airplanes are prone to stall easily. They fly best at a high airspeed and/or high wing AOA, relative to their low mass.

Similar to conventional airplanes, paper airplanes generate wingtip vortices in their wake. See Fig. 4i-iii.

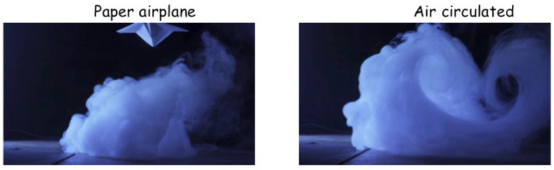


Fig. 4i-iii. Paper airplane flying through smoke. [45]

Typical flight trajectory

The typical trajectory of a paper airplane flight can be split into distinct phases: See Fig. 4i-iv.

- **(i) Climb:** Once thrown from an altitude, the paper airplane transfers its momentum to the air to generate lift and forward motion. If the paper airplane generates positive lift then, it gains altitude.

  Drag causes the paper airplane to quickly lose velocity, and therefore, it quickly loses momentum.

- **(ii) Stall.** The paper airplane looses forward velocity due to drag, reducing momentum and lift generation. Eventually, it is unable to generate sufficient lift to fly and the paper airplane may stall. How and when the stall occurs depends on wing design and atmospheric conditions.

  The stall can be abrupt and all lift is lost, or more typically, it is less dramatic.

  After a stall, the paper airplane may then enter a downward glide under beneficial wing design and flight conditions.

- **(iii) Glide:** After a stall, if the paper airplane regains a positive AOA and airspeed by the nose turning down and losing altitude. These actions allow the paper airplane to generate enough lift to fly again.

  Flight can be maintained in a glide downwards by trading altitude for airspeed and lift. This trade-off is described by the glide ratio achieved. Eventually, the paper airplane glides towards the ground.

  However, just above the ground, lift may be boosted temporarily by ground effect. This dynamic allows the paper airplane's nose can be raised and the wing AOA to narrow just prior to hitting the ground.

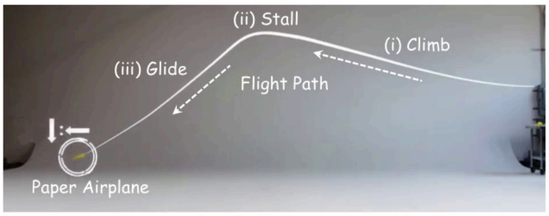


Fig. 4i-iv. Paper airplane trajectory
split into a climb, stall, and glide phases. [38]

J. Wing design according to Newtonian mechanics.

Wings come is all shapes and sizes, each with their own particular advantages and disadvantages in how they push air down to create lift. See Fig. 4j.

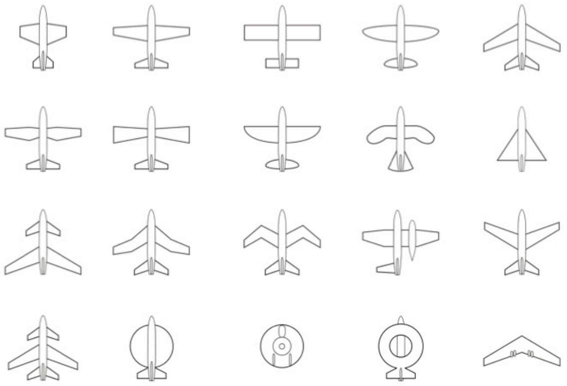


Fig. 4j. Examples of different wing designs – top view. [14]

Given a strong enough engine thrust, airspeed and a positive AOA, even a barn door could theoretically generate sufficient lift to fly. In fact, some fighter jets have flown with only one wing on one occasion, and with their wings folded (unextended) on another occasion. In both cases significantly higher airspeed and AOA than usual was required to maintain flight. This implies that the engines were used to help compensate for the loss of lift from a reduced wingspan. For example:

- In 2016, a F-15 fighter jet landed with only one wing following a mid-air collision with an A-4 Skyhawk during training.
- In 1960, a US Vought F-8 Crusader took-off from Naples, Italy with its wings still folded (unextended). It later landed safely.

Some wing design considerations include:

- The need to maintain laminar airflow over the wing.
- Wing curvature and the Coanda effect.
- Wing design needs to be supported by sufficiently strong and light materials to maintain the aircraft's integrity.
- The features of the aircraft (e.g. engine power, aspect ratio, momentum, propeller or jet, fuel and lift efficiency, location of the engines on the aircraft, ….),
- The circumstances (e.g. maintenance issues, runway conditions, airport restrictions, regulations, ….).
- The purpose of the aircraft (commercial passenger transport, cargo, private business passenger transport, private leisure, military, STOL, VTOL, ….), as well as
- The preferences and priorities of the owners and pilots.

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5. MORE ON NEWTON

A. *Key forces.*

This paper defines Engine Thrust as $\text{Force}_{\text{PROPELLERS}}$, which is the force created by the wings accelerating air backwards. For a jet engine, this is the force created by the engine accelerating exhaust gases backwards. The reactive equal and opposite force is called $\text{Thrust}_{\text{PROPELLERS}}$, as shown by the equation: See Fig. 5a-(i-ii).

$$\text{Force}_{\text{PROPELLERS}}\ (\text{Engine Thrust}) = \text{Thrust}_{\text{PROPELLERS}}$$

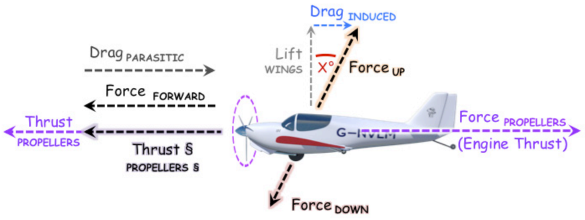

Fig. 5a-i. Key forces acting on an airplane with a low wing AOA in level flight.

$\text{Thrust}_{\text{PROPELLERS}}$ can be split into two forces shown below:

$$\text{Thrust}_{\text{PROPELLERS}} = \text{Thrust \S}_{\text{PROPELLERS \S}} + \text{Force}_{\text{DOWN}}$$

The equation above shows that $\text{Thrust \S}_{\text{PROPELLERS \S}}$ is the residual force left from the engine thrust (or $\text{Thrust}_{\text{PROPELLERS}}$), after the wings have diverted some of the engine thrust downward ($\text{Force}_{\text{DOWN}}$) in order to generate lift. See Fig. 5a-ii.

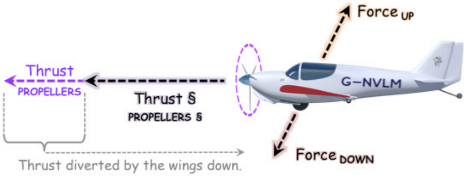

Fig. 5a-ii. Forces pushing the airplane forwards and up.

As the downward and upward forces on the wings are equal, ($\text{Force}_{\text{DOWN}} = \text{Force}_{\text{UP}}$), the equation above can be re-sated as:

$$\underset{\textit{(Engine Thrust)}}{\text{Thrust}_{\text{PROPELLERS}}} = \underset{\textit{(Forwards)}}{\text{Thrust \S}_{\text{PROPELLERS \S}}} + \underset{\textit{(Upwards)}}{\text{Force}_{\text{UP}}}$$

In other words, $\text{Thrust}_{\text{PROPELLERS}}$ (Engine Thrust) pushes the airplane forwards ($\text{Thrust \S}_{\text{PROPELLERS \S}}$) and up ($\text{Force}_{\text{UP}}$). This explanation of the forces acting on an airplane is consistent with how momentum is transferred from the wings to the air to generate lift, which reduces the aircraft's momentum.

Key definitions:

$\text{Thrust}_{\text{PROPELLERS}}$ = The equal and opposite force to Engine Thrust ($\text{Force}_{\text{PROPELLERS}}$).

$\text{Thrust \S}_{\text{PROPELLERS \S}}$ = $\text{Thrust}_{\text{PROPELLERS}}$ minus the force used to generate lift ($\text{Force}_{\text{DOWN}}$).

Key forces – low wing AOA

For stable, horizontal flight at a low wing AOA, the two key forces acting on the airplane are described further:

1) **$\text{Thrust \S}_{\text{PROPELLERS \S}}$** is the residual force from the propellers (or jet engines) that pushes the airplane horizontally ahead ($\text{Force}_{\text{FORWARD}}$) to overcome parasitic drag and provide airspeed. Parasitic drag ($\text{Drag}_{\text{PARASITIC}}$) is the resistance from the inertia of the air to the airplane's forward motion.

   At a low wing AOA, in this example, almost all engine thrust is used to generate forward motion, and negligible amounts are directed downwards to provide lift.

2) **Force_{UP}** is the reactive, equal and opposite upward force to the downward force ($\text{Force}_{\text{DOWN}}$) exerted by the wings from accelerating the air flown through down, as summarised by the equation:

   $$\text{Force}_{\text{DOWN}} = \text{Force}_{\text{UP}}$$

   The upward and downward forces act to reduce $\text{Thrust}_{\text{PROPELLERS}}$ to $\text{Thrust \S}_{\text{PROPELLERS \S}}$.

   For example, as explained in the previous section, if the wings accelerated more air downwards each second (higher m/dt) to a higher velocity (higher dv), the downward force would increase (higher $\text{Force}_{\text{DOWN}}$). Assuming no change in the engine thrust (constant $\text{Thrust}_{\text{PROPELLERS}}$), this action would have two key results: See Fig. 5b-ii.

   - Increase the upward force (Force_{UP}); thereby increasing lift.
   - Reduce the force pushing the airplane forwards (lower $\text{Thrust \S}_{\text{PROPELLERS \S}}$), thereby reducing the aircraft's airspeed.

   Force_{UP} can be split between the two perpendicular vectors: the vertical part (Lift), and the backward horizontal part ($\text{Drag}_{\text{INDUCED}}$), shown by the equation:

   $$\text{Force}_{\text{UP}} = \underset{\textit{(vertical)}}{\text{Lift}} + \underset{\textit{(horizontal)}}{\text{Drag}_{\text{INDUCED}}}$$

   The net forward force generated by the wings and propellers, which push the airplane horizontally forwards, is the sum of the forward force and induced drag (a negative amount). This aspect is summarised by the equation: See Fig. 5a-iii.

   $$\text{Force}_{\text{NET FORWARD}} = \text{Force}_{\text{FORWARD}} + \text{Drag}_{\text{INDUCED}}$$

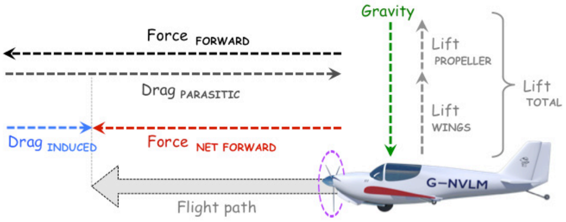

Fig. 5a-iii. Vectors of forces acting on an airplane.

B. *Total lift generated.*

Lift is the vertical force generated directly upwards against gravity. The total lift generated by an airplane is the sum of the lift contributed directly by the propeller thrust (or jet engine thrust) and wings, which can be summarised by the equations (not expressed as vectors): See Fig. 5a-(i-iii) and Fig. 5b-(i-iv).

$$\text{Lift}_{\text{TOTAL}} = \text{Lift}_{\text{WINGS}} + \text{Lift}_{\text{PROPELLERS}\,\S}$$

The wings and propellers (or jet engines) both accelerate a mass of air each second (m/dt) to a velocity (dv). Therefore, the equation for lift above can be broken down into the factors ‘m/dt’ and ‘dv’ as follows:

$$\begin{aligned}\text{Lift}_{\text{TOTAL}} &= (m/dt \;*\; dv)_{\text{WINGS}}\\ &\quad + (m/dt \;*\; dv)_{\text{PROPELLERS}\,\S}\end{aligned}$$

$$\text{Lift}_{\text{TOTAL}} = (m/dt \;*\; dv)_{\text{TOTAL}}$$

Where:

$$\begin{aligned}\text{Lift}_{\text{PROPELLERS}\,\S} &= (m/dt \;*\; dv)_{\text{PROPELLERS}\,\S}\\ &= m/dt_{\text{PROPELLERS}\,\S} \;*\; dv_{\text{PROPELLERS}\,\S}\end{aligned}$$

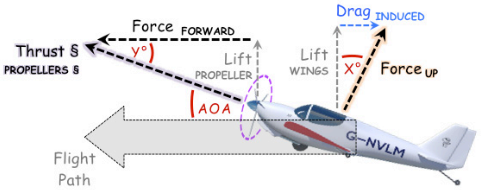

Fig. 5b-i. Total lift generated by wings and propellers in slow flight.

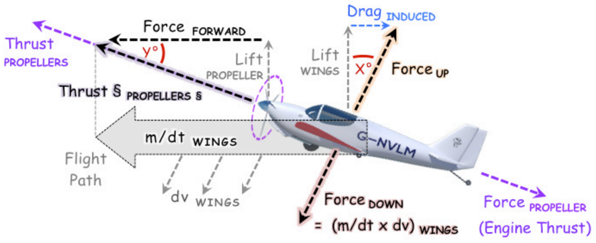

Fig. 5b-ii. Key forces acting on an airplane in level flight with a nose-up configuration (slow flight).

Angle Y°

The angle Y° that the propeller thrust is directed depends on the wing AOA and the angle that the propellers are attached to the fuselage. Propellers are often designed to be angled slightly upwards for an airplane in cruise flight, in order to boost lift slightly.

This dynamic means that as the wing AOA increases, the lift generated from the wings typically declines, while the lift generated from the propellers (or jet engines) increases.

Propeller thrust

Similar to the lift generated by the wings, the airflows from the propellers (or jet engines) can be assessed according to Newtonian mechanics based on the mass flow rate. The same logic shown for propellers can be applied to explain the forces acting on a jet engine.

The propellers accelerate a small mass of air each second ($m/dt_{\text{PROPELLERS}}$) to a high velocity ($dv_{\text{PROPELLERS}}$). This action creates a force ($\text{Force}_{\text{PROPELLERS}}$). The reactive equal and opposite force provides engine thrust to push the airplane forwards, as summarised by the equations: See Fig. 5b-iii.

$$\begin{aligned}\text{Force}_{\text{PROPELLERS}} &= (m/dt \;*\; dv)_{\text{PROPELLERS}}\\ &= m/dt_{\text{PROPELLERS}} \;*\; dv_{\text{PROPELLERS}}\\ &= \text{Thrust}_{\text{PROPELLERS}}\end{aligned}$$

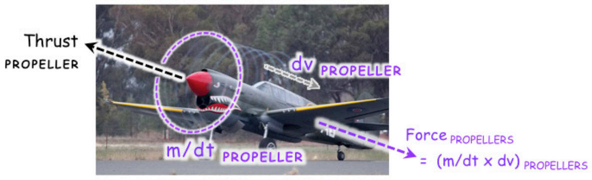

Fig. 5b-iii. Thrust generation by a propeller. [14]

As explained above, for an airplane $\text{Thrust}_{\text{PROPELLERS}}$ can be split into two forces shown below:

$$\text{Thrust}_{\text{PROPELLERS}} = \text{Thrust}\,\S_{\text{PROPELLERS}\,\S} + \text{Force}_{\text{DOWN}}$$

If the propellers are angled upwards in flight (e.g. nose-up configuration with a high wing AOA), then the engine thrust ($\text{Thrust}\,\S_{\text{PROPELLERS}\,\S}$) can be split into vertical and horizontal vectors, as shown by the equation: See Fig. 5b-iv.

$$\text{Thrust}\,\S_{\text{PROPELLERS}\,\S} = \underset{\textit{(horizontal)}}{\text{Force}_{\text{FORWARD}}} + \underset{\textit{(vertical)}}{\text{Lift}_{\text{PROPELLERS}}}$$

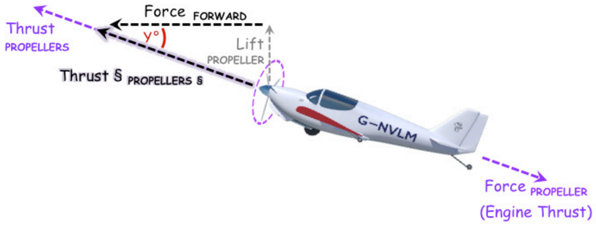

Fig. 5b-iv. Force acting on the airplane due to the forces from the propellers.

These horizontal and vertical forces can also be expressed using the trigonometry of a right angled triangle and Pythagoras theorem, as shown by the equations:

$$\text{Force}_{\text{FORWARD}} = \text{Thrust}_{\text{PROPELLERS}\,\S} \;*\; \text{Cos}\,(Y°)$$

$$\begin{aligned}\text{Lift}_{\text{PROPELLERS}\,\S} &= \text{Thrust}_{\text{PROPELLERS}\,\S} \;*\; \text{Sin}\,(Y°)\\ &= (m/dt \;*\; dv)_{\text{PROPELLERS}\,\S}\end{aligned}$$

Constant lift curve

The mix of how lift is generated from propellers and wings between ‘m/dt’ and ‘dv’ can be represented graphically, along the constant lift curve. This curve includes the combined totals of ‘m/dt’ and ‘dv’ from the wings and propeller. See Fig. 5b-v.

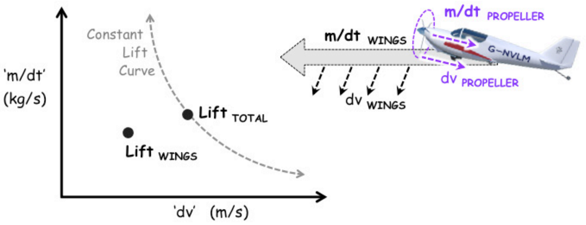

Fig. 5b-v. Constant lift curve.

There are a restricted number of possible methods to combine ‘m/dt’ and ‘dv’ available to pilots – which are all along the constant lift curve. For example, to enable the airplane to maintain altitude (lift), with any change in AOA the pilot adjusts the flight configuration to manage how the aircraft generates lift from ‘m/dt’ and ‘dv’.

C. Wings vs. propellers.

Wings, propellers and rotors create forces in the same manner, as described by the same Newtonian equation based on the mass flow rate (Force = m/dt * dv). See Fig. 5c-i.

- Wings move through stationary air pushing it downwards, which generates an equal and opposite upward force.
- Whereas, propellers and rotors spin on a fixed hub, pushing stationary air downwards or backwards. This action generates an equal and opposite force.

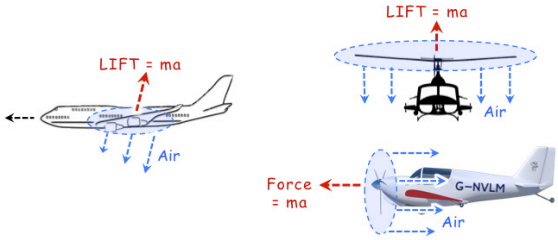

Fig. 5c-i. Newtonian v. Fluid mechanics.

The assertion above is significant as it contradicts claims that propellers and jet engines create forces differently as compared to wings. In addition, the Newtonian explanation is logical given that wings, propellers, rotors, and jet engine fan blades have the same basic shape, design and function. See Fig. 5c-ii.

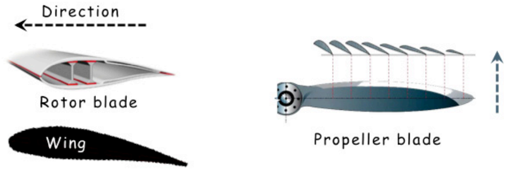

Fig. 5c-ii. Propeller, rotor, fan blades and wing. [14]

D. Wings vs. jet engines.

A rocket is compared to a jet to illustrate the point above.

All the lift generated by the rocket is from the engines, regardless of its orientation and flight path, as the rocket has no wings.

The thrust generated by the engines of the rocket and jet can be described by Newtonian mechanics based on the mass flow rate (Thrust = m/dt * dv).

In contrast to the rocket, the proportion of vertical lift generated by the jet’s wings and engines changes as the flight path changes.

For the jet in a vertical climb, all lift is generated from the engines and none from the wings. As the jet reduces its angle of climb and changes its flight path towards the horizontal direction, the wings start generating more of the lift required to fly. At the same time, the engines provide less lift.

The manner in which the lift force is generated from the wings or engines changes, but the Newtonian equation used to calculate the lift does not change (Force = m/dt * dv). This argument is significant and has not been made elsewhere before. See Fig. 5d.

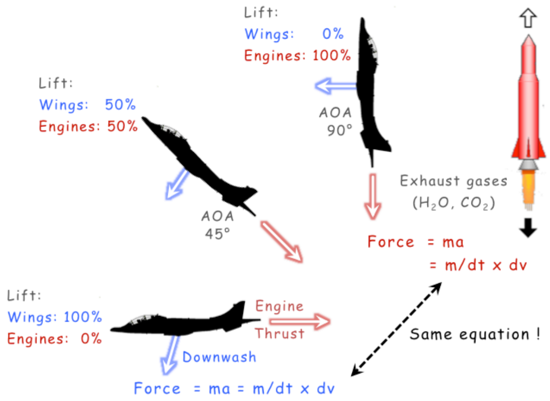

Fig. 5d. Changing contribution of wings and engines towards the lift generated.

Significance

The concept of equating how wings, rotors, propellers, and jet engines create a force based on the same Newtonian equation is novel and innovative. It is not to be found in any textbook.

E. Induced drag.

The dynamics of induced drag is a controversial subject, and therefore, merits additional and extensive explanations.

The Newtonian approach presented in this paper is significant because:

- It differs significantly from the prevailing view by experts such as NASA. NASA's explanation of induced drag is provided separately below.
- It makes induced drag easier to understand, apply to flight conditions, and explain changes in the lift generated.
- It is easier to calculate induced drag more accurately, as compared to the prevailing methods.

According to Newtonian mechanics, induced drag is the backward horizontal component of the upward force generated by the wing.

Wings generate downward and upward forces at oblique angles, which depend on the angle that the downwash is accelerated down. In turn, this angle depends on factors such as the wing AOA and the wing shape. See Fig. 5e-(i-ii).

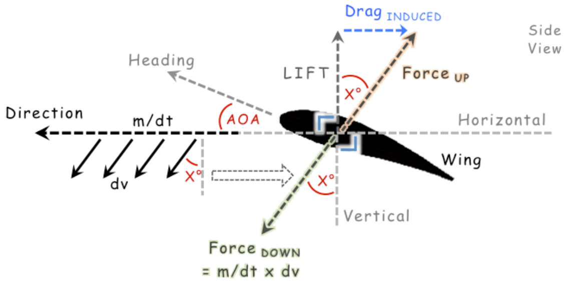

Fig. 5e-i. Forces acting on a wing.

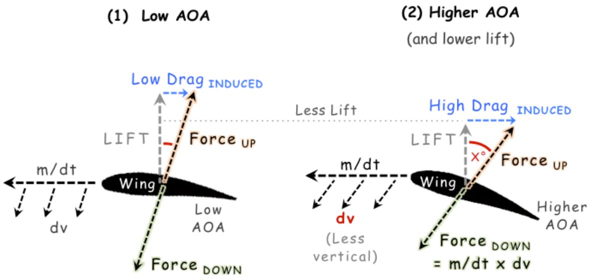

Fig. 5e-ii. Induced drag at different wing AOAs.

Assumptions fro induced drag

For simplicity, analysis compartmentalises induced drag elsewhere in this paper and assumes that induced drag is negligible or not significant to the analysis. This means that induced drag is only taken into account when it is significant to the analysis or if the amount of induced drag changes in the analysis described.

Analysis of induced drag

The upward force (Force_{UP}) acting on a wing can be split into the two perpendicular vectors: the vertical part (Lift), and the horizontal part ($\text{Drag}_{\text{INDUCED}}$), as summarised by the equations:

$$\text{Force}_{\text{UP}} = \text{Lift} + \text{Drag}_{\text{INDUCED}}$$

This is a closed system. An increase in induced drag causes a reduction in lift, absent any change in the upward force (Force_{UP}) from the wings.

The Force_{UP} is the hypotenuse of the right-angled triangle and the forces involved can be split as follows:

$$\begin{aligned} \text{Lift} &= \text{Force}_{\text{UP}} * \text{Cos}(X°) \\ &= (m/dt * dv) * \text{Cos}(X°) \end{aligned}$$

$$\text{Drag}_{\text{INDUCED}} = \text{Force}_{\text{UP}} * \text{Sin}(X°)$$

The Newtonian method described above provides an entirely new approach to explain and analyse induced drag, which shows that:

- The induced drag ($\text{Drag}_{\text{INDUCED}}$) acts in the opposite direction to the forward force generated by the propellers ($\text{Force}_{\text{FORWARD}}$). i.e. $\text{Drag}_{\text{INDUCED}}$ pushes the airplane backwards, which detracts from the forward airspeed.
- The induced drag generated depends on downwash velocity (dv) and angle at which the wings accelerate air down.
- For an airplane in cruise flight at a low wing AOA, the induced drag is negligible and lift approximately equals the upward force, as shown by the equation:

  $$\text{Lift} = \text{Force}_{\text{UP}}$$

  More precisely, at a low downwash angle, X° is nearly zero, and therefore, Cos (0°) = 1. Consequently, the lift generated is assume to equal the upward force, as summarised by the equation:

  $$\text{Lift} = \text{Force}_{\text{UP}} = (m/dt * dv) * \text{Cos}(X°)$$

  ➔ $$\text{Lift} = \text{Force}_{\text{UP}} = (m/dt * dv) * 1$$

  ➔ $$\text{Lift} = \text{Force}_{\text{UP}} = m/dt * dv$$

- At a low wing AOA the propellers contribute little towards lift. Lift can be almost entirely generated by the wings.
- At a higher wing AOA the downwash (m/dt) is accelerated down at a less vertical angle. Consequently, the reactive upward force is also at a less vertical angle, causing increased induced drag, and reduced lift generated. The wings are generating lift less efficiently. To maintain the same amount of lift generated, a much larger upward force (Force_{UP}) is required.
- A higher wing AOA also can affect lift by:
  - Increasing the wing reach, and thus, increasing 'm/dt'.
  - Altering the Coanda effect on the topside of the wing.
  - Directing more propeller thrust downwards.

6. WING AIRFLOWS

A. *Two absolute wing airflows.*

The two key wing airflows involved in the active generation of lift by an airplane with a positive wing AOA include: See Fig. 6a-(i-ii).

1) The **underside** of the wing pushes air down.
2) The **topside** of the wing pulls air down, helped by the Coanda effect and low air pressure on top of the wing.

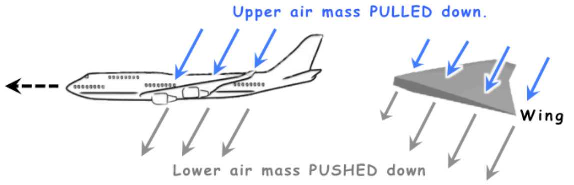

Fig. 6a-i. Two airflows on a wing.

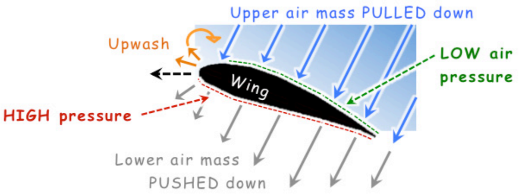

Fig. 6a-ii. 2D diagram of wing airflows.

These two wing airflows are described:

1) **The underside of a wing** accelerates the air flown through down and slightly forwards. This action creates high pressure on the underside surface of the wing, based on the standard equation for pressure (Pressure = Force /Area). See Fig. 6a-iii.

2) **On the topside of the wing** a zone of low air pressure arises, due to the forward movement of the wing creating a relative vacuum behind it. This low air pressure zone accelerates the air above the wing down and slightly forward. See Fig. 6a-iv. In addition:
   - The leading edge of the wing initially pushes the air up and forwards, creating upwash.
   - Any curvature on the topside of the wing can enhance downward airflows of the air above the wing due to the Coanda effect.
   - If the air above the wing pulled down does not reach the trailing edge of the wing by the time that the wing has moved forwards. Then turbulence and a stall can be triggered.

The lift process produces a **pressure differential on the wing**; Low pressure on the topside of the wing and high pressure on the underside of the wing. This paper argues that these pressure patterns observed are a **consequence** of the airflows and resultant forces, and **not a cause** of lift.

If the air above the wing is not accelerated downwards fast enough to reach the trailing edge of the wing. Then turbulence, airflow separation can arise, which can trigger a stall.

Two wing airflows shown separately:

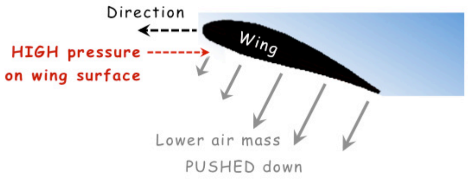

Fig. 6a-iii. Underside of the wing pushes air down

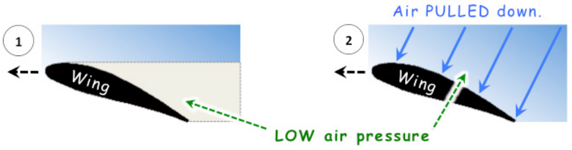

Fig. 6a-iv. Area of low pressure behind the topside of the wing.

Path of air molecules

The wing airflows generated can be illustrated by the theoretical path of air molecules above and below the wing. See Fig. 6a-(v-vi).

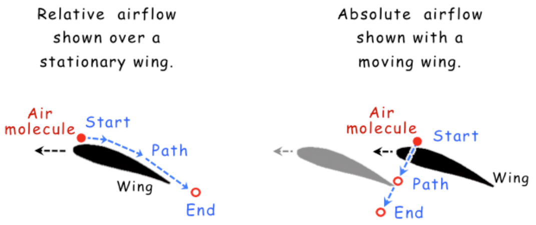

Fig. 6a-v. Theoretical path of an air molecule starting above the wing.

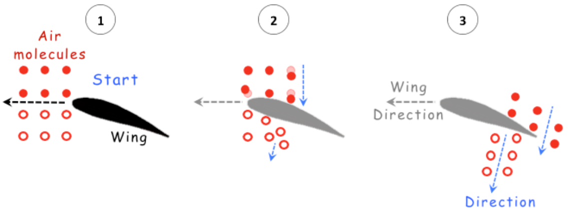

Fig. 6a-vi. Theoretical path of air molecules over a wing.

B. *Wing airflow considerations.*

Additional considerations: See Fig. 6b-i.

- The airflows created depend on factors such as the airfoil size and shape, airspeed, and wing AOA.
- Aircraft momentum affects the velocity that the air flown through is accelerated to (dv), particularly for the lower air mass.
- The higher the airspeed, then the stronger the area of low air pressure on top of the wing, and the faster the upper mass is pulled down (higher 'dv' above the wing).
- 'dv' varies across the wingspan due to differences in wing thickness and depth (chord). Consequently, 'dv' is least at the wingtips and greatest at the wing root.
- The upper and lower airflows can have different velocities (dv) as they have different causal factors. Their velocities are likely to be similar as they are accelerated by the same wing with the same airspeed.

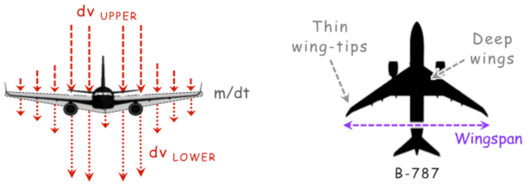

Fig. 6b-i. Wing airflows and downwash velocities (dv).

- The mass of air accelerated by the wing each second (m/dt) can be different above and below the wing.
- After the wing has passed forwards, the lower and upper air masses accelerated by the wing continue to descend due to the momentum gained.
- This action pushes and pulls the surrounding air to circulate the air behind the aircraft. See Fig. 6b-ii.

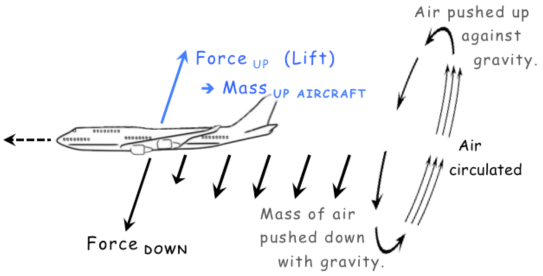

Fig. 6b-ii. Wings circulate air in their wake.

- Any curvature on the topside of the wing can enhance downward airflows of the air above the wing due to the Coanda effect, as explained below.
- Slats, flaps slots, and air brakes also affect wing airflows, and therefore, the forces generated.

C. *The topside of the wing is critical for lift.*

The optimum wing AOA maximizes the combined airflow re-directed or accelerated downwards by the underside and topside of the wing, and therefore, the generated force.

The top airflow is sensitive to changes in wing AOA due to the Coanda effect. Whereas, the lower airflow does not rely on the Coanda effect, which makes it more stable and less sensitive to changes in the wing AOA. Stalls arising due to disrupted airflow on the topside of wings provide evidence of this difference in airflow sensitivity.

Consequently, attention is focused on the upper airflow when analysing how changes in AOA or other wing characteristics affect lift. The implication is that the topside of the wing can displace a much greater airflow under ideal conditions, as compared to the underside of the wing.

In other words, the lift generation of the topside of the wing is considered to be a lot more variable, as compared to the underside of the wing. However, experiments need to be done to confirm this assertion.

For example, as the wing AOA increases (at constant airspeed), more air is displaced down by both sides of the wing. But the increase is greater on the topside of the wing, due to the Coanda effect; until a stall is triggered. See Fig. 6c.

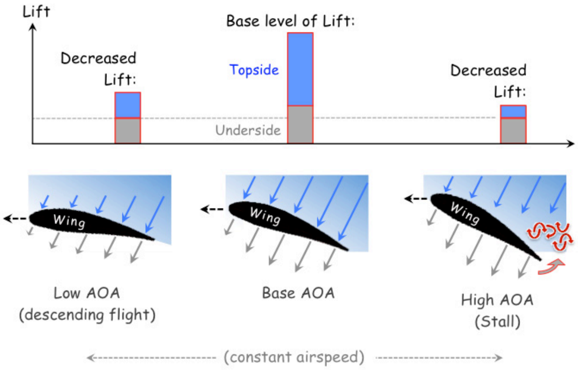

Fig. 6c. Upper wing airflow is highly sensitive to changes in wing AOA.

The bar graph in the image above represents the mass of air flown through and accelerated down each second (m/dt); for each wing configuration. Consequently, it is a key factor that directly affects the amount of lift generated.

This analysis is extremely significant.

D. The Coanda effect – Spoon experiment.

Fluid flow naturally follows a curved surface due to the Coanda effect. For example, water falling from a tap is re-directed by the curved side of a spoon. See Fig. 6d-i.

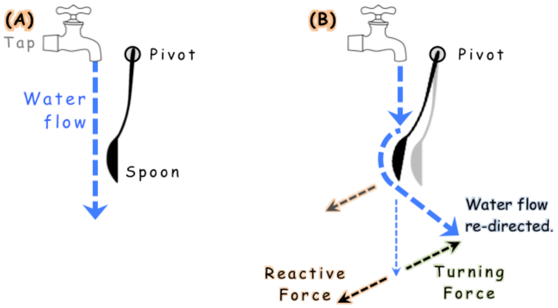

Fig. 6d-i. Coanda effect – Spoon experiment.

According to Newtonian mechanics, the water flow passively re-directed by a spoon due to the Coanda effect creates a small turning force due to the change in momentum of the water flow. The reactive equal and opposite force pushes the spoon diagonally to the left sideways and downward. The spoon pivots to the left as far as the reactive force allows.

Wind tunnel experiments

Wind tunnel experiments demonstrate airflows arising due to the Coanda effect on the topside of a curved airplane wing, as well as the turbulence that arises on a flat wing. See Fig. 6d-ii.

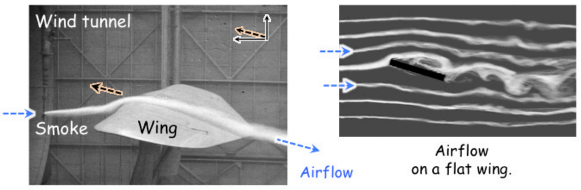

Fig. 6d-ii. Airflow on curved and flat wings. [7]

In general, wings produce a stronger Coanda effect with laminar (smooth / non-turbulent) airflow at a lower AOA, higher airspeed, and where the wings are deepest (largest chord, such as near the fuselage). Conversely, the Coanda effect is weakest at high AOA, slower airspeeds, and where the wings are narrow (small chord, such as at the wing tips). See Fig. 6d-iii.

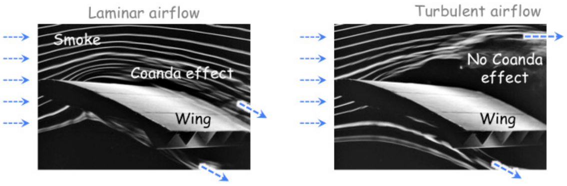

Fig. 6d-iii. Smooth vs. turbulent airflows on a wing. [10]

The flat undersides of wings are typically designed to push air down without inducing any Coanda effect.

Coanda effect and fighter jet wings

Some fighter jet wing and fuselage designs show pronounced curvature that maximizes the Coanda effect. See Fig. 6d-iv.

Fig. 6d-iv. Curved fuselage designs of jets. [8][9]

The Coanda effect helps to explain why airplanes keep the topside of wings clear of any obstructions that could disrupt the upper airflows. For example fighter jets almost always carry their payloads under their wings. There are usually other reasons for this as well (eg. ease of maintenance, many bombs are dropped so cannot be on the top of wings, ….). See Fig. 6d-v.

Fig. 6d-v. Fighter jet payloads. [14]

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7. AERODYNAMIC STALLS

A. *Newtonian explanation of a stall.*

Brief summary

An aerodynamic stall occurs when the wings cease to generate enough lift for an airplane to continue to fly.

Analysis below shows that the stall and stall recovery process are consistent with Newtonian mechanics. Therefore, the analysis supports the argument that Newtonian physics and absolute airflow analysis explains lift.

A new insight gained from this analysis is that stalls and stall recovery are shown to depend critically on how the downward acceleration of the air (dv) is affected by the wings.

The Newtonian approach provides a methodology to improve pilot training and wing design for stall avoidance; as well as a method to better predict stalls. Consequently, these developments can provide advantages for safety and aircraft performance.

It is fundamentally flawed to use relative airflows to analyse stalls. Consequently, it is also flawed to use relative airflows and fluid mechanics (Navier-Stokes equations) to explain the lift generated by an airplane wing in flight.

The Newtonian explanation in more detail

A stall typically occurs in a slow flight configuration, with a high wing AOA and/or low airspeed. The wings are generating low ‘m/dt’ and ‘dv’. Lift is being boosted by the propeller. The lift composition for slow flight and a stall is shown graphically in Fig. 7a-i.

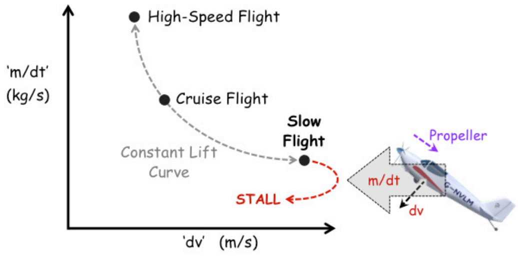


Fig. 7a-i. Lift composition for slow flight

The total lift generated in slow flight is shown by the equations:

$$\text{LIFT}_{\text{TOTAL}} = \text{LIFT}_{\text{WINGS}} + \text{LIFT}_{\text{PROPELLERS}}$$

$$\text{LIFT}_{\text{TOTAL}} = (\text{Low m/dt} * \text{low dv})_{\text{WINGS}} + \text{LIFT}_{\text{PROPELLER}}$$

A high wing AOA configuration pre-stall can produce significant induced drag, and is inefficient at generating lift. Consequently, a high wing AOA can trigger a stall despite significant throttle (engine thrust) being applied. See Fig. 7a-iv.

For an aircraft in slow flight (high wing AOA and low airspeed), a stall can be triggered when the upper air mass is no longer accelerated downwards fast enough (low dv) to reach the trailing edge of the wing.

Consequently, at the trailing edge the low air pressure on top of the wing now pulls air from below the upward, to the topside of the wing. This action causes airflow separation and turbulence at the trailing edge, which disrupts laminar (smooth) airflow on top of the wing See Fig. 7a-(ii-iii).

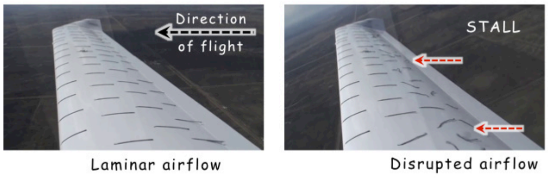


Fig. 7a-ii. Wing airflows in a stall.

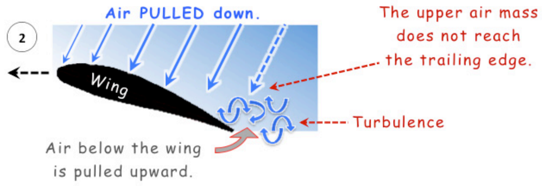


Fig. 7a-iii. Wing airflows – lower air mass is pulled up.

Airplanes can fly with a certain amount of wing turbulence. However, if enough turbulence arises and enough lift is lost, the entire wing can stall, and cease to generate lift.

According to Newtonian mechanics, the increased airflow separation and turbulence causes reduced ‘m/dt’ and ‘dv’, and therefore, a loss of lift (Lift = m/dt * dv). If lift declines enough. Then the aircraft can cease to fly, and falls like a stone. See Fig. 7a-iv below.

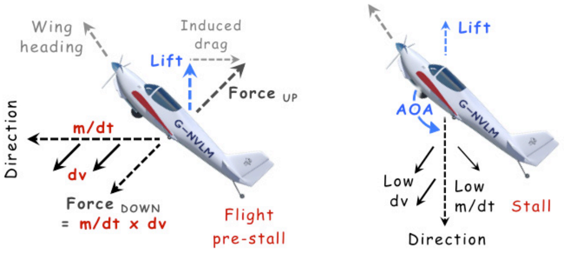


Fig. 7a-iv. Absolute airflows and Newtonian forces acting on a wing, pre- and post stall.

As the airplane descends vertically after a stall, the wing AOA increases due to the change in the direction of the relative airflow, which is now from below the wing upward. See Fig. 7a-iv above.

An airplane's vertical descent post-stall can be illustrated by an airplane in a spin, following a stall. A spin is when an airplane is in an uncontrolled corkscrew descent. See Fig. 7a-v.

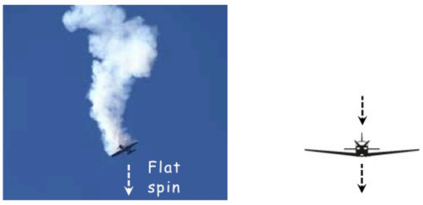


Fig. 7a-v. Airplane in a spin. [47]

The underside of the wings still pass through a low mass of air each second (low m/dt). However, the topside of the wings displace a negligible amount of air and the Coanda effect is negligible. See Fig. 7a-iv above.

The air passed through by the wings each second (m/dt), is accelerated at a low velocity (low dv) away from the airplane, to create an upward force. In a spin the upward force is called drag, not lift. However, in this situation lift and drag are synonymous. Although, a difference is that drag is usually defined as the force required to physically push the air out of the airplane's downward path. [1] Nonetheless, the same equation using Newtonian mechanics based on the mass flow rate (Force = m/dt * dv) can be employed to calculate the lift and drag experienced by the airplane in free-fall descent. See Fig. 7a-vi.

Fig. 7a-vi. Drag on an airplane in a free-fall descent.

This process for an airplane in free-fall descent is similar to a skydiver generating drag in a free-fall descent, which is logical. See Fig. 7a-vi.

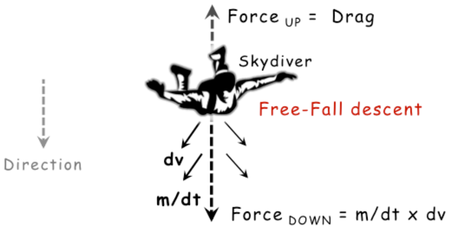
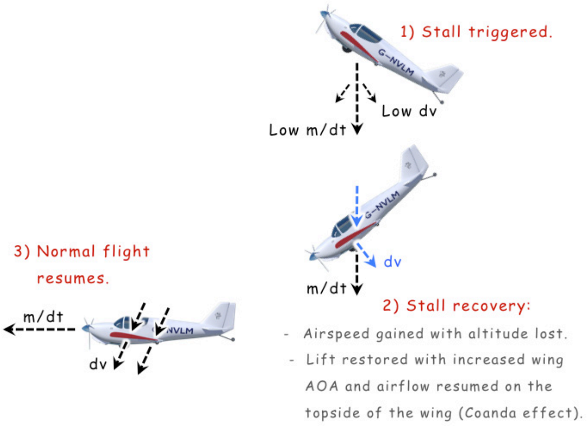


Fig. 7a-vii. Drag on a skydiver in a free-fall descent.

B. Stall recovery explained by Newtonian mechanics.



See Fig. 7b. Stall recovery process.

The stall recovery process is consistent with the Newtonian explanation for lift and stalls.

Assuming no spin is triggered, a typical stall recovery is achieved by pointing the nose of the airplane downwards as the aircraft descends, thereby reducing the wing AOA. As shown in image (2) in Fig. 7b above.

1) This change allows the topside of the wing to resume pulling air downwards, assisted by a resumption in the Coanda effect.
2) Consequently, 'm/dt' and 'dv' increase, boosting lift, and causing flight to be regained. The airplane resumes normal flight or a glide once buoyancy is re-established.
3) In addition, pointing the nose downward angles the underside of the wings to push the air in one direction downwards, rather than in many directions downward. This change focuses the lift generated by the wings more efficiently.
4) If the engines were turned off before the stall, then an engine re-start would assist the stall recovery by boosting the aircraft's airspeed.

At the start of the stall an aircraft typically has low airspeed, and therefore, little momentum. A stall recovery is possible as the aircraft gains vertical airspeed as it descends, causing the aircraft's kinetic energy and momentum to increase. The then aircraft regains the capacity to accelerate the air flown through downwards sufficiently fast (dv), and therefore, to generate enough lift to fly.

Often a stall does not last long in modern airplanes, which are designed to quickly regain stable flight with ease. For example, once in a stall the aircraft's nose is designed to decline without any pilot interference, due to the weight and balance design of the airplane.

8. EQUATIONS FOR LIFT AND DRAG

A. Standard equations for drag and lift.

Newtonian physics explains the standard equation for drag: [1]

Drag = 0.5 (Aircraft Velocity^2 * Surface Area
* Air Density * Drag Coefficient)

The standard equation for drag is simply a mathematical description of how drag is observed to vary in practice with different parameters. Until now there has been no adequate explanation of the physics involved.

All parameters of the standard equation for drag (aircraft velocity, air density, surface area, and drag coefficient) affect the mass of air flown through each second by the fuselage (m/dt $_{\text{DRAG}}$); and/or the velocity to which this air is accelerated away from the aircraft (dv $_{\text{DRAG}}$). Therefore, the drag equation can be explained by Newtonian mechanics based on the mass flow rate (Force = ma = m/dt * dv); as shown by the analysis below. In subsonic flight, drag arises primarily from the fuselage, vertical tail section, engines, and spanwise wing airflow. See Fig. 8a-i.

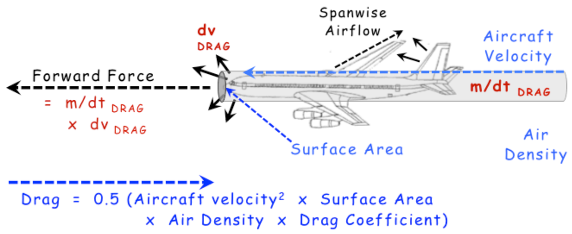


Fig. 8a-i. The standard and Newtonian equations for drag.

The analysis is provided in three steps:

(i) The Newtonian and standard equations are equated:

Newtonian = Standard equation
Force $_{\text{FORWARD}}$ = Drag
m/dt $_{\text{DRAG}}$ x dv $_{\text{DRAG}}$ = 0.5 (Velocity^2 * Surface Area * Air Density * Drag Coefficient)

(ii) The equation above is revised as follows:

m/dt $_{\text{DRAG}}$ = (Velocity * Surface Area * Air Density) (a)
x dv $_{\text{DRAG}}$ * 0.5 (Velocity * Drag Coefficient) (b)

(iii) Then the two parts of the Newtonian equation (m/dt $_{\text{DRAG}}$ and dv $_{\text{DRAG}}$) are correlated to two different parts of the standard equation of drag, (a) and (b):

m/dt $_{\text{DRAG}}$ = Velocity * Surface Area * Air Density (a)
= (Velocity * Surface Area) * Air Density
= **Volume $_{\text{DRAG}}$ /dt** * Air Density
= m/dt $_{\text{DRAG}}$

dv $_{\text{DRAG}}$ = 0.5 * Velocity * Drag Coefficient (b)

Where: Velocity = Aircraft velocity.
Surface Area = Surface area of the aircraft fuselage, engines, and tail in the direction of travel.

It is no coincidence that the standard equations for lift and drag are similar, as they are explained by Newtonian mechanics.

Newtonian physics explains the standard equation for lift: [1]

Lift = 0.5 (Aircraft Velocity^2 * Wing Area
* Air Density * Lift Coefficient)

The standard equation for lift is simply a mathematical description of how lift is observed to vary in practice with different parameters. Until now there has been no adequate explanation of the physics involved.

All parameters of the standard equation for lift (aircraft velocity, air density, surface area, and drag coefficient) affect the mass of air flown through each second by the wings (m/dt); and/or the velocity to which this mass of air is accelerated downward (dv). Therefore, the standard equation for lift can be explained by Newtonian mechanics based on the mass flow rate (Force = m/dt * dv); as shown by the analysis below: See Fig. 8a-ii.

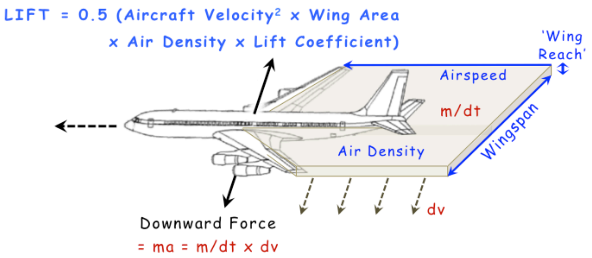


Fig. 8a-ii. The standard and Newtonian equations for lift.

The analysis is provided in three steps:

(i) The Newtonian and standard equations are equated:

Newtonian = Standard equation
Force $_{\text{DOWN}}$ = Lift
m/dt * dv = 0.5 (Velocity^2 * Wing Area * Air Density * Lift Coefficient)

(ii) The equation above is revised as follows:

m/dt * dv = 0.5 (Velocity * Wing Area * Air Density) (a)
* (Velocity * Lift Coefficient) (b)

(iii) Then the two parts of the Newtonian equation (m/dt and dv) are correlated to two different parts of the standard equation of lift, (a) and (b):

m/dt = 0.5 * Velocity * **Wing Area** * Air Density (a)
= 0.5 * Velocity * (**Wingspan** * **Chord**) * Air Density
= (Velocity * Wingspan * (**0.5** * **Chord**)) * Air Density
= (Velocity * Wingspan * **Wing Reach**) * Air Density
= **Volume /dt** * Air Density
= m/dt

dv = Velocity * Lift Coefficient (b)

Where: Velocity = Aircraft velocity.
Wing Area = Wingspan * Chord
Wing Reach = 0.5 * Chord * [Lift Coefficient]
(Wing reach includes part of the lift coefficient.

However, for simplicity the lift coefficient element is not shown in the equation above. See the full explanation. [2])

Summary

The analysis above shows that Newtonian mechanics can explain the standard equations for drag and lift. In addition the analysis demonstrates that the drag and lift coefficients depends on ‘dv’, the velocity to which the fuselage or wings accelerates the air.

B. *Why lift increases with airspeed.*

The Newtonian approach can be used to better explain all aspects of lift generation. For example, if two almost identical light aircraft (A) and (B) are compared. Where Aircraft (B) has a higher mass, it needs to generate more lift to fly. See Fig. 8b.

Aircraft (B) can generate extra lift (Lift = m/dt * dv) by increasing its airspeed and engine power, while maintaining its wing AOA. As a result it flies through a greater mass of air each second (higher m/dt); which it accelerates downwards to a higher velocity (higher dv).

Therefore, lift increases in the heavier Aircraft (B), due to higher ‘m/dt’ and higher ‘dv’, as shown by the equation:

Higher Lift = higher m/dt * higher dv

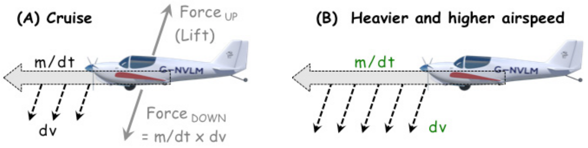


Fig. 8b. Two aircraft compared.

Also, Aircraft (B) has a greater momentum, and therefore, it has more momentum to transfer to the air to generate lift.

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C. *Why lift quadruples if airspeed doubles.*

The Newtonian explanation for lift based on the mass flow rate (Lift = m/dt * dv), can be used to explain why vertical lift is proportional to the square of horizontal aircraft velocity, as described by the standard equation for lift, for an airplane in flight, as follows: Fig. 8c-i.

Lift = 0.5 (**Aircraft Velocity**^{2} * Air Density
* Wing Area * Lift Coefficient)

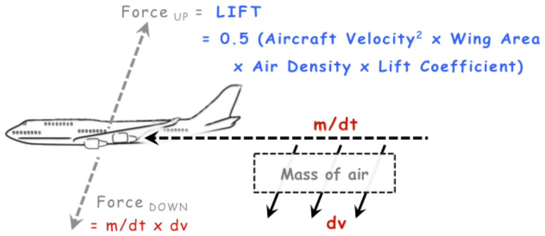

Fig. 8c-i. Newtonian forces acting on an airplane.

According to Newtonian mechanics, if the aircraft’s velocity doubles, then lift quadruples as explained below:

- An aircraft travelling twice as fast, so the wings fly through twice the mass of air each second (2x m/dt);
- The wings accelerate this air to twice the velocity downward as before (2x dv), as aircraft momentum has also doubled (Momentum = mass * velocity).

The combined effect of these two changes above is to quadruple the Force $_{\text{DOWN}}$, and therefore, also quadruple the reactive Force $_{\text{UP}}$ as well as the lift generated. This dynamic is summarised by the equations: See Fig. 8c-ii.

$$4 * \text{Force}_{\text{DOWN}} = (2 * m/dt) * (2 * dv)$$
$$= 4 * (m/dt * dv)$$
$$= 4 * \text{Force}_{\text{UP}} \text{ (Lift)}$$

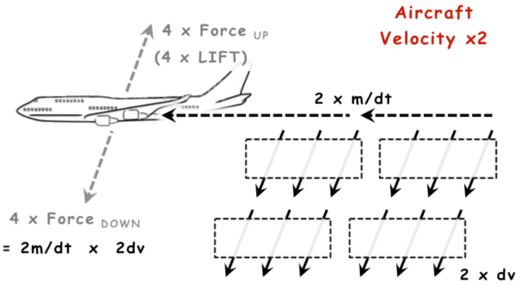

Fig. 8c-ii. Lift ⇔ Aircraft Velocity^2

9. FLIGHT MANOEUVERS

A. Overview.

Newtonian mechanics based on the mass flow rate is used to explain lift during all flight manoeuvers, using the equation:

$$Lift = m/dt\ x\ dv \tag{5}$$

Flight manoeuvers can be shown to affect lift (Lift = m/dt * dv), depending on how the mass of air flown through each second (m/dt) and/or the velocity to which this air is accelerated downwards (dv) change with the alterations in aircraft orientation and circumstances (e.g. airspeed, wing AOA, …). See Fig. 9a-i.

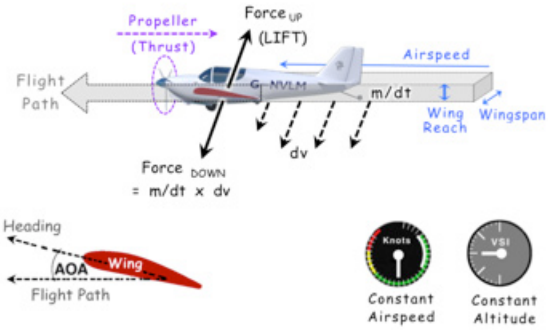

Fig. 9a-i. Newtonian forces acting on a wing.

The flight manoeuvers analysed below include: [2]

- Cruise flight.
- Increased airspeed.
- Inverted flight.
- Take-off / ‘nose-up’ climb.
- Flaps.
- Slow flight.
- Change in aircraft mass.
- Final approach to a runway.
- Landing.
- Vertical climb.
- Vertical descent.
- Steep descent.
- Power-off descent.
- Wing AOA.
- Banking and adverse yaw.
- Side slipping.
- Propeller forces.

Flight manoeuvers can be accurately described using Newtonian explanation for lift (Lift = m/dt * dv). Variations in ‘m/dt’ and ‘dv’ change how the lift is generated based on aircraft configuration changes. The composition of lift between ‘m/dt’ and ‘dv’ can be shown graphically for different configurations. See Fig. 9a-(ii-iii).

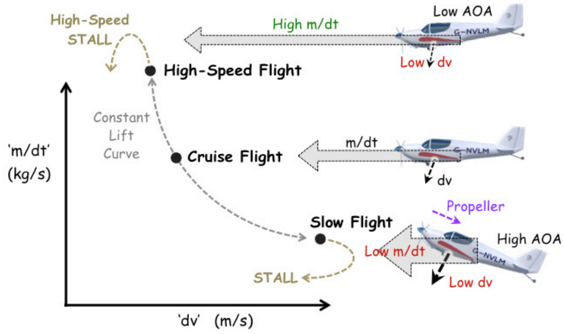

Fig. 9a-ii. Lift composition – ‘m/dt’ and ‘dv compared.

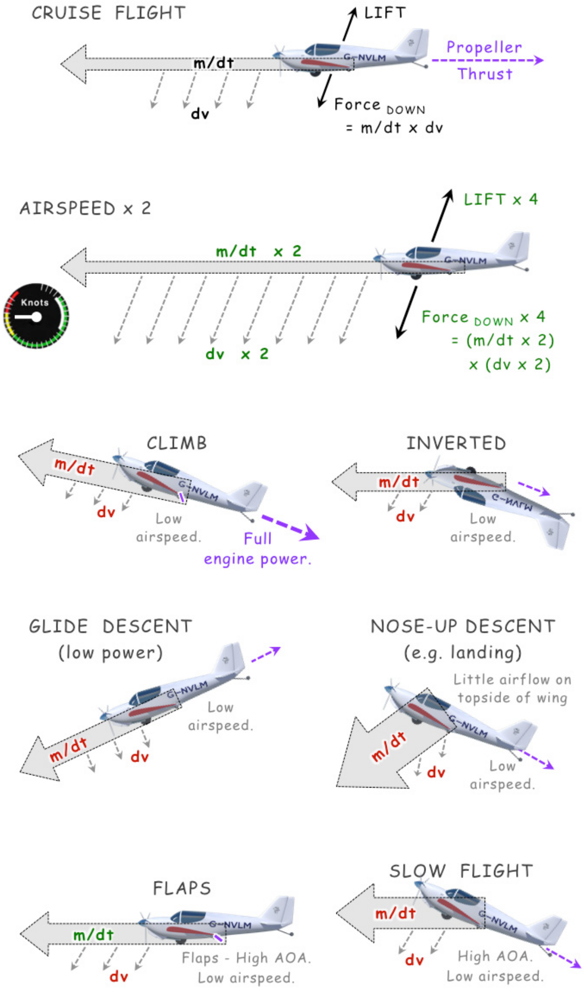

Fig. 9a-iii. Key flight manoeuvers summarized. [2]

Colour key is described as compared to cruise flight:

m/dt or dv = Increased ‘m/dt’ or ‘dv’; and therefore, increased lift generated from these sources.

m/dt or dv = Decreased ‘m/dt’ or ‘dv’; and therefore, decreased lift generated from these sources.

B. Examples.

Inverted flight and take-off are provided as examples of flight manoeuvers analysis according to Newtonian mechanics.

Inverted flight

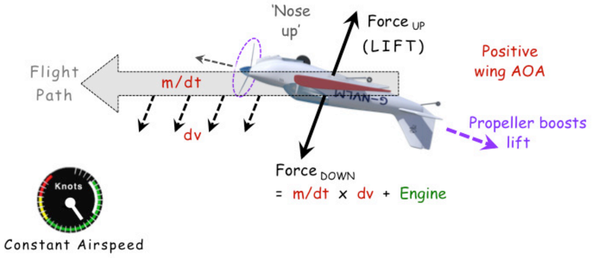

Fig. 9b-i. Inverted flight.

In an inverted flight at constant altitude and airspeed. The airplane's configuration needs to be slightly raised for the wings to have a positive AOA. Consequently, this configuration means that: See Fig. 9b-i.

- The airplane's orientation is less aerodynamic to the direction of flight, which increases drag. Higher engine power is required to compensate for this extra drag.
- Any wing curvature is now facing downwards, reversing the benefits of any Coanda effect, and reducing 'm/dt' and the lift generated. Aerobatic airplanes tend to have symmetrical wings to negate this problem.
- Lift is increased by a higher wing AOA and 'nose up' attitude. This increases m/dt, 'dv' and the contribution towards lift by the engines (propellers) as they are angled slightly upwards.

In short, to maintain airspeed and altitude, additional engine power and increased wing AOA are needed to offset the overall negative aerodynamic effects of flying inverted (higher drag). See Fig. 9b-(ii-iii).

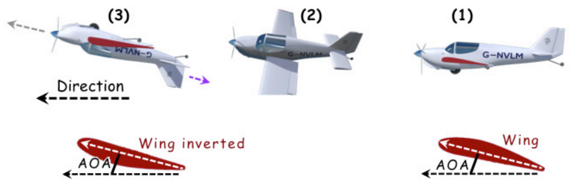

Fig. 9b-ii. Transition from cruise to inverted flight.

Fig. 9b-iii. Inverted flight at extremely low altitude.

Take-off / climb

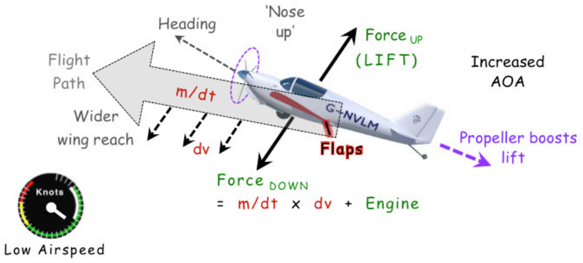

Fig. 9b-iv. Take-off and 'nose-up' climb with flaps.

A typical take-off or 'nose-up' climb uses high (maximum) engine power, flaps, and wide wing AOA. Lift is prioritised over airspeed in this configuration. Ideally, the aircraft gains altitude as much altitude as possible, providing a steep ascent at a low airspeed. As compared to cruise flight: See Fig. 9b-iv.

- 'm/dt' is lower due to lower airspeed, despite an increased wing reach from a higher wing AOA. The wings are flying through less air each second, as it is flying more slowly.
- 'dv' is slightly lower due to the slightly lower airspeed and decreased aircraft momentum. The airplane has less momentum to transfer to the air, and less capacity to accelerate the air downwards.
- Also, an increased wing AOA means that the wings push the air down at a less vertical angle, reducing 'dv' and lift, while increasing induced drag.
- The engines (propellers) are angled upwards to boost lift, at the cost of lower airspeed.
- Extending the flaps can increase the wing AOA, curvature (camber), wing reach, induced drag, and lift.

The configuration described above is typical climb after take-off when the aircraft is fully laden and therefore, has a low airspeed. In contrast, a climb at a high airspeed can increase 'm/dt' and 'dv', and therefore, boost the rate of climb.

The significant difference between the aircraft's heading and actual direction flown, which provides a high AOA, can be observed in airliners taking off. When airliners take-off close to their maximum take-off weight (MTOW) they struggle to climb and gain altitude. See Fig. 9b-v.

Fig. 9b-v. Example of an airliner taking-off badly; and gaining altitude very slowly.

10. PRACTICAL ASPECTS OF FLIGHT

A. *Overview*

The different practical aspects of flight are explained by Newtonian mechanics based on how the mass of air flown through (m/dt) and the velocity to which this air is accelerated (dv), vary to affect lift (Lift = m/dt * dv), based on the conditions involved. See Fig. 10a-(i-ii).

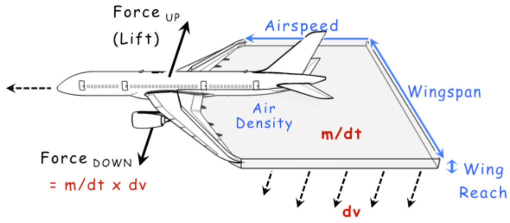

Fig. 10a-i. Newtonian forces acting on an airplane.

The practical aspects of flight include: [2]

- Engine positions on the wings.
- Altitude.
- Wind and air currents.
- Hovering.
- Gliding.
- Anhedral vs. Dihedral wings.
- Winglets.
- Prandtl flying wing.
- Tail section and pitch.
- Canards.
- Variable sweep wings.
- Variable pitch propellers.
- Double propellers.
- Biplanes and box-wings.
- Airfoil thickness.
- Drogue parachute.
- Delta wing aircraft.
- Variable angle of incidence.
- Ground effect.
- Supersonic flight.
- Sonic boom.

Key conclusions:

All practical aspects of flight can be accurately described using Newtonian explanation for lift (Lift = m/dt * dv). Variations in 'm/dt' and 'dv' change how the lift is generated depending on the circumstances.

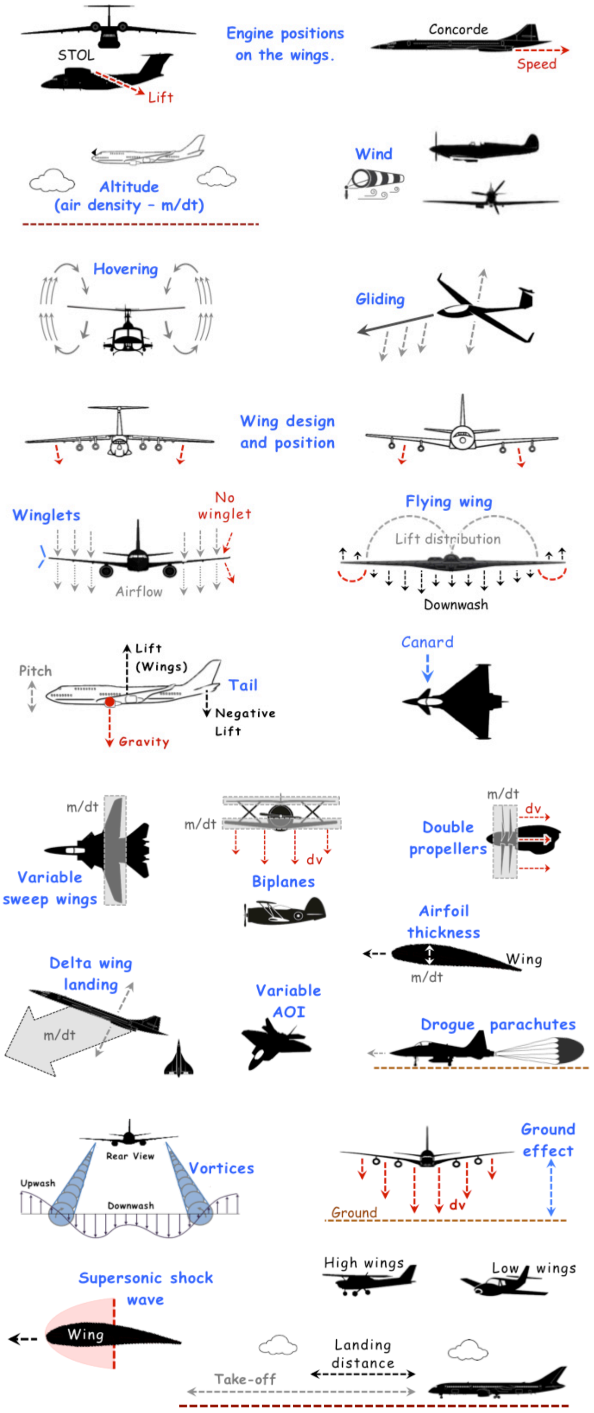

Fig. 10a-ii. Some practical aspects of flight. explained by Newtonian mechanics.

See the full report for the detailed explanations [2]

B. *Examples of practical aspects of flight.*

The ability of Newtonian mechanics to provide simple and straight forward explanations for the practical aspects of flight observed, is particularly significant because fluid mechanics (Navier-Stokes equations) fails to do this.

Consequently, the key insights that highlight the usefulness of the Newtonian approach to understand the practical aspects of flight are summarised below, which include:

- Winglets.
- Airfoils generate no drag in flight.
- Airfoil thickness.
- Variable sweep wings.
- Biplanes.
- Delta wing aircraft landing.
- Ground effect.
- Sonic boom.
- Evidence for downwash velocity (dv).
- Other aeronautical enigmas

Theses key practical aspects of lift are summarised below:

C. *Winglets.*

The prevailing view is that wingtip (wake) vortices are a by-product of flight arising due to high-pressure air under the wings moving towards the low-pressure air above the wings. Wingtip vortices are seen as a cause of extra drag (especially induced drag) and are detrimental to flight. Consequently, winglets are seen beneficial to lift and flight as they reduce induced drag. [1][42] See Fig. 10c-i.

Fig. 10c-i. Wing-tip vortices. [42]

In contrast to the prevailing view, according to Newtonian mechanics, winglets can be beneficial if they improve the efficiency at which air is displaced downward by the wings. See Fig. 10c-ii.

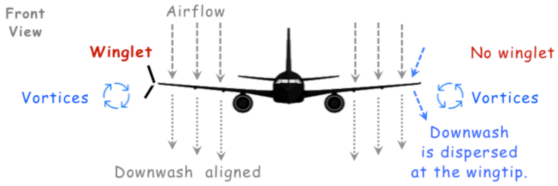

Fig. 10c-ii. Different airflows at the wingtips due to winglets.

D. *Airfoils generate no drag in flight.*

Wings in flight generate almost no parasitic drag in subsonic flight, except for drag arising from spanwise airflow (which is only significant at transonic or faster). On ground roll during take-off, wings generate parasitic drag as they push air out of their path; pushing the air upward and downward. However, in flight wings push almost all the air flown through downwards to generate lift and induced drag. See Fig. 10d-iv.

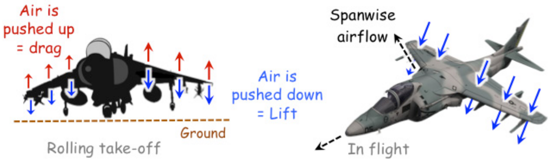

Fig. 10d-iv. Harrier wings pushing air downwards.

This aspect of flight helps to explain why no airspeed or momentum is lost on take-off flare, as airplanes transition from ground roll (generating parasitic drag) to flight (generating lift). See Fig. 10d-(v-vi).

Fig. 10d-v. Little airspeed is lost on take-off flare.

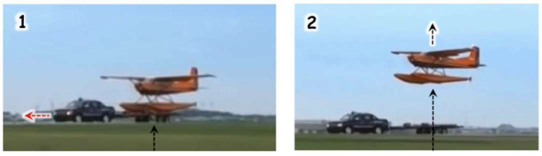

Fig. 10d-vi. Floatplane taking off from a trailer.

Insights: The argument above can be used to explain enigmas, including:

- How a frisbee can be thrown distances that are multiple times further than a baseball of similar mass.
- How a swordfish can swim in water at over 100 km/hr, which is faster than a cheetah can run on the land at 100 km/hr. In addition, this logic also explains Grays paradox; how dolphins can swim as fast as 40 km/hr.
- Why a flying wing (blended wing) design generates significantly less drag as compared to a conventional airplane with a tubular fuselage. This logic indicates that **hypersonic flight** can be best achieved by minimizing drag using the flying wing design.

Lift/Drag ratios (L/D ratios), are commonly used to measure how efficiently wings generate lift. The logic above also indicates that L/D ratios are inaccurate and flawed because wings generate no parasitic drag in flight. Therefore, L/D ratios mostly measure 'Lift / Induced Drag', which is primarily a function of the wing AOA at subsonic speeds, and not wing efficiency. See Fig. 10d-ix.

E. *Airfoil thickness.*

The importance of wing thickness to the amount of lift generated has been overlooked in the standard equation for lift and fluid mechanics (Navier-Stokes equations).

In addition, aspect ratios, which are commonly used to measure how efficiently wings generate lift, are inaccurate and flawed because it fails to consider how wing thickness affects lift. Identical aircraft having wings with the same aspect ratio but different wing thicknesses, produce different 'm/dt', and therefore, different lift profiles.

Thin airfoils were common only in the early 20th Century and disappeared quickly afterwards. See Fig. 10e-vii.

Fig. 10e-vii. Old and modern airfoils compared. [14]

The WWII B-24 bomber was fitted with a relatively thick wing (the Davis wing). It achieved low drag with a short chord and high aspect ratio. See Fig. 10e-viii.

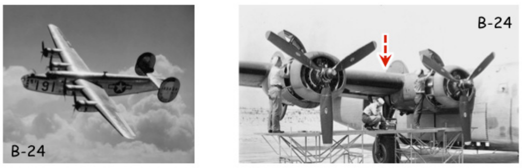

Fig. 10e-viii. Davis wing of the B-24 bomber. [14]

The Newtonian approach solves this problem by taking wing thickness into account, via the wing reach used to calculate lift.

The mass of air flown through each second (m/dt) depends on wing thickness and wingspan, among other things. In turn, wing reach depends on wing thickness and AOA.

Longer wingspans and thicker airfoils (higher wing reach) fly through a greater mass of air each second (higher m/dt), which generates more lift (Lift = m/dt * dv) at subsonic airspeeds. See Fig. 10e-ix.

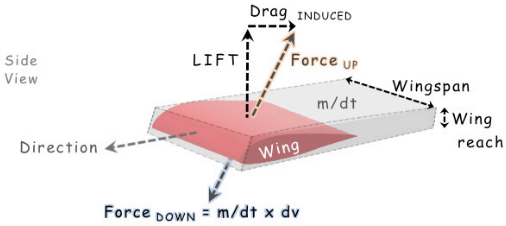

Fig. 10e-ix. Forces on a wing.

F. *Variable sweep wings.*

Variable sweep wing designs allow aircraft to adjust the contributions made from 'm/dt' and 'dv' to generate lift (Lift = m/dt * dv) and to suit the aircraft's performance requirements.

For example, the US Navy's F-14 Tomcat uses minimum wing sweep (maximum wingspan, with the wings fully extended), for low-speed manoeuvers such as short take-offs or landings (STOL) from aircraft carriers. See Fig. 10f-x.

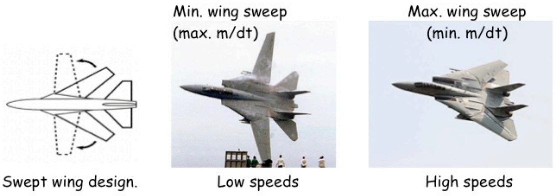

Fig. 10f-x. Variable wing sweep wing design.

According to Newtonian mechanics, at low airspeeds a lack of aircraft momentum limits the wing's capacity to accelerate the air downwards (low dv) to generate lift.

Therefore, to maximize the lift generated and enable flight at low airspeeds, the wings are extended to maximize 'm/dt'. The increase in 'm/dt' compensates for the low 'dv'. Low-speed flight is important as it allows the F-14 to limit the runway distance required on landing. See Fig. 10f-xi.

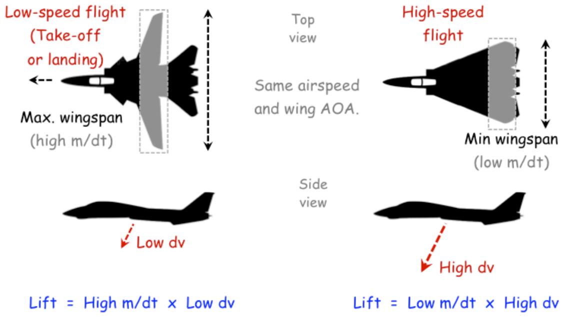

Fig. 10f-xi. F-14 Tomcat wing sweep positions.

Conversely, in high-speed flight the wing sweep is maximised (and the wingspan minimised, with the wings retracted close to the fuselage), due to the following benefits provided:

- In high-speed flight lift is not a restriction, as it flies through a high mass of air each second (high m/dt).
- The min. wing-sweep configuration minimizes aerodynamic drag from spanwise flow, and delays the shock waves that arise from supersonic flight.
- At high-speed, the F-14 has significant momentum, and therefore, ability to accelerate air down aggressively (high dv).

G. *Biplanes.*

Biplanes generate significantly less lift per m^2 of wing area, as compared to a monoplane with the same overall wingspan, wing area, and basic wing design. A problem is that there is currently no explanation for this phenomenon and no equation to quantify the effects of a second wing.

According to Newtonian mechanics, this phenomenon arises because a biplane's wings are aligned above / below each other. The top wing is accelerating the same vertical section of air downwards as the bottom wing. The biplane has half the effective wingspan, which limits the total mass of air displaced down each second (low m/dt). See Fig. 10g-(i-ii).

Fig. 10g-i. Wings accelerate air downwards. [14]

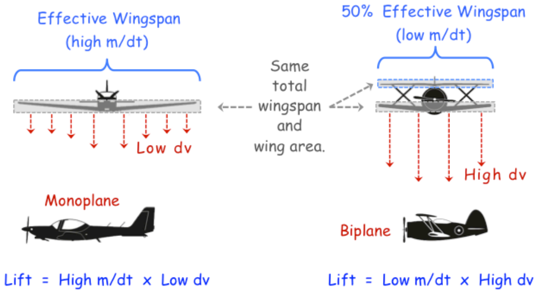

Fig. 10g-ii. 'm/dt' and 'dv' of a monoplane and biplane.

For example, if a biplane and monoplane's wings have the same wing design, wing area, wing AOA, and airspeed; then both airplane's wings fly through the same mass of air each second (m/dt). However, the biplane accelerates an air mass that is roughly half as wide as compared to the monoplane.

To generate lift, the biplane has no choice but to accelerate the low mass of air flown through each second (low m/dt) to a high velocity (high dv), as compared to the monoplane; as summarised by the equations:

Monoplanes: Lift = high m/dt * low dv

Biplanes: Lift = low m/dt * high dv

Biplanes' method of lift generation, which generates lift proportionately more on 'dv' than 'm/dt', as compared to monoplanes, is energy-inefficient because kinetic energy is proportional to the downwash velocity squared (K.E. = $0.5 mv^2$).

H. *Delta wing aircraft landing.*

High-speed aircraft favour delta wing designs, as they prioritize drag minimization over lift generation. The drawback is high stall airspeed arising due to poor lift generation at low-speed manoeuvers such as landing and taking-off. Consequently, delta wing aircraft can only generate enough lift to land or take-off at high wing AOA, as compared to swept wing airliners. See Fig. 10h-i.

Fig. 10h-i. Delta wing aircraft landing at high AOA. [14]

The problems for delta wing at low airspeeds include:

- The wings fly through a low mass of air each second (low m/dt).
- The aircraft has little momentum, and therefore, little capacity to accelerate downwash (low dv).

Landing at a high wing AOA maximizes the 'm/dt' and allows more of engine power to be directed downwards to boost the lift generated. See Fig. 10h-ii.

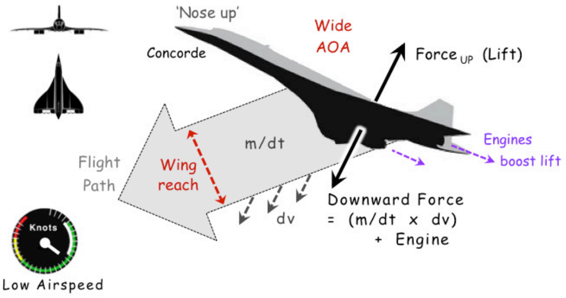

Fig. 10h-ii. Newtonian forces acting on Concorde on approach to landing at low airspeed.

The downside of this high wing AOA configuration is that the downwash is pushed downwards at a more oblique (or less vertical) angle. This dynamic increases induced drag, and therefore, reduces the lift generated. This is because the amount of downwash accelerated in the vertical direction is reduced. See Fig. 10h-iii.

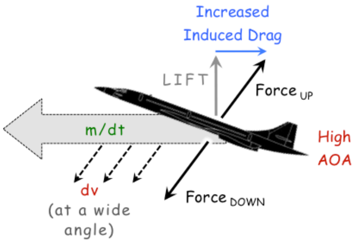

Fig. 10h-iii. High induced drag at low AOA.

I. *Ground effect.*

Ground effect is a phenomenon seen where airplanes benefit from extra lift close to the ground. For example, on landing airplanes appear to float temporarily just above the runway; causing the airplane to cover relatively longer distances prior to touching down. See Fig. 10i-i.

Fig. 10i-i. Ground effect observed on landing.

Ground effect can also boost lift on take-off.

Currently, there is no equation available than can quantify aspects of ground effect such as: the vertical distance at which ground effect is significant, how much extra lift is generated, and the extra runway distances needed.

Newtonian mechanics provides a framework to quantify ground effect, based primarily on the downwash velocity (dv) generated by the wings. The ground provides the wings with a more solid surface to push against, to generate lift. See Fig. 10i-ii.

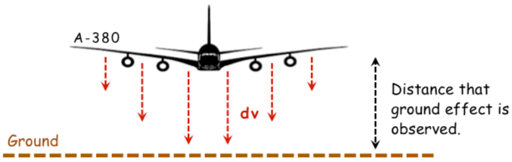

Fig. 10i-ii. Calculation of ground effect distances.

The Newtonian explanation is consistent with the sensation that with ground effect, the airplane seems to float on a cushion of air close to the ground.

The Newtonian approach explains why: See Fig. 10i-iii.

- A glider that generates low downwash velocity (low dv), experiences ground effect only a short distance above the ground, despite its long wingspan.
- A fighter jet (Harrier) that generates high downwash velocity (high dv), experiences ground effect a long distance above the ground, despite it short wingspan.

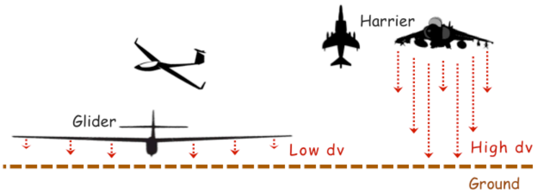

Fig. 10i-iii. Ground effect distances compared.

J. *Sonic boom.*

A sonic boom is due to a rapid change in pressure from shock waves that arise when an aircraft accelerates the air flown through to a speed faster than the speed of sound (Mach 1). The change in pressure can arise due to the wings, fuselage, engines, or tail accelerating the air flown through. See Fig. 10j-i.

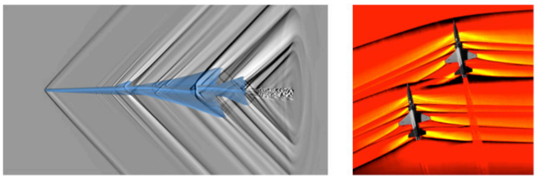

Fig. 10j-i. Shock waves from an aircraft travelling at supersonic speed, which creates a sonic boom. [1]

Evidence for transonic and supersonic shock waves in jets is provided by expansion fans; A cone-shaped water condensation, also called the shock collar. Vapour condensation appears due to the lower localised pressure near the trailing edge of the wing, where the shock wave is. See Fig. 10j-ii.

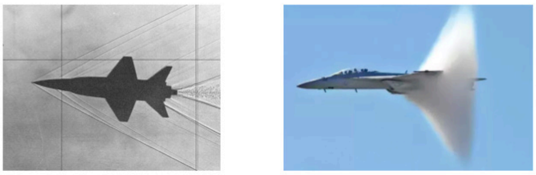

Fig. 10j-ii. Jets at supersonic speeds. [1]

Newtonian mechanics can explain the factors that affect the sonic boom, as these factors also affect the velocity that aircraft accelerate the air flown through:

- Aircraft mass, size, and shape.
- Attitude, and weather or atmospheric conditions.
- The lift distribution across the wing.

In particular, a heavier aircraft can trigger a sonic boom at lower airspeeds. [1] According to Newtonian mechanics, the heavier aircraft has greater mass and momentum, and therefore, greater capacity to accelerate the air flown through to a higher speed (higher dv) to trigger a sonic boom.

Insights: The Newtonian approach provides a new explanation for sonic booms.

Efforts to mitigate sonic booms should analyse how the aircraft accelerates the air it flies through. Rather than simply looking at the resultant pressure changes that the aircraft cause by accelerating the air flown through.

K. Evidence for downwash velocity (dv).

Condensation can sometimes be evident on the top of wings when certain atmospheric conditions (sufficient humidity) are present. For condensation to occur, the wing needs to accelerate the air mass above the wings downwards sufficiently fast to lower the internal temperature of the air. The top surface of the wing acts as a condensation point. Condensation does not always occur.

Condensation does not often arise under the wing, because the air is accelerated away from the wing and towards the atmosphere. Therefore, there is no condensation point. Whereas, condensation arises on the topside of the wing, because the air is accelerated towards lower air pressure on top of the wing.

Condensation above airliner's wings due to low air pressure indicates how far the wings affect the air above them. The distance away from the wing and distribution across the wingspan of the condensation, indicates how the topside of the wings accelerate the air above them downwards, to generate lift. See Fig. 10k-i.

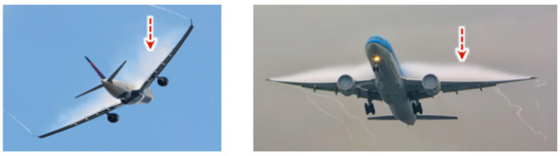

Fig. 10k-i. Wing condensation on airliners. [18][19]

The assertion that wing condensation is associated with 'dv' and lift generation is supported by the following observations:

- Wing condensation is not observed on the ground run (when no lift is being generated), prior to take-off. But it is seen on flare and take-off by airliners (when lift is being generated). See Fig. 10k-ii.

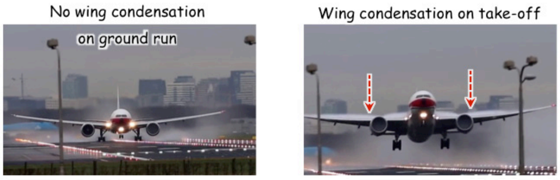

Fig. 10k-ii. Wing condensation on take-off. [20]

- Similarly, wing condensation is observed on airliners on approach to landing (when lift is generated). But it is not evident once the aircraft has landed on the runway (when lift is not generated). See Fig. 10k-iii.

Fig. 10k-iii. Wing condensation on approach. [21]

L. Other aeronautical enigmas.

Other aeronautical enigmas solved in the Section Practical Aspects of Flight include:

a) Differences in glide ratios.
b) Stall risk from a tailwind after take-off.

These enigmas are explained in more detail below.

(a) How a heavy commercial airliner (e.g. A-320), can have a **glide ratio** of 17:1, which is more than double the glide ratio of small light airplane of 8:1 (eg. Cessna 172). This is a significant difference in glide ratios. This aspect is despite the A-320 having only a 40% higher **aspect ratio** of 10.3; as compared to a 7.3 aspect ratio for a Cessna 1742. See Fig. 10l-i.

Fig. 10l-i. A-320 and Cessna 172
glide ratios compared.

(b) Why a **stall risk** arises when an airplane turns downwind, after engine failure on take-off into a strong headwind. See Fig. 10l-ii.

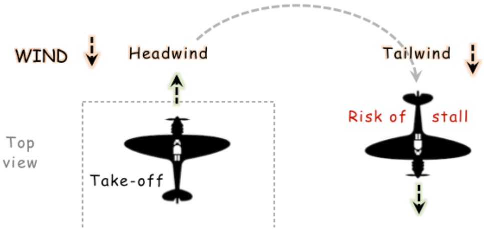

Fig. 10l-ii. Stall risk after take-off.

11. DISCUSSION OF RESULTS

A. *Historical perspective.*

Since 1903, commercial aviation grew as aircraft have continuously become better in almost every sense; lighter, faster, bigger, more reliable, more efficient, better controls, cheaper, ….. However, technological progress can be split into two broad periods: 1903-1947, and post 1947.

In the period 1903-1947, airplane performance and design evolved at an accelerated pace, going from simple machines to complex jets with swept wings capable of supersonic flight.

Biplanes were flying in WWI, in the 1920's monoplanes with thicker wings became the norm, the first jet flew in 1939, the first flying wing flew in 1945, and supersonic flight was achieved in 1947.

After 1947 fundamental technological progress slowed dramatically. Most developments such as VTOL, variable sweep wings, flexible wings, and hypersonic flight were not incorporated into commercial airliners. This means that the new technology has not been sufficiently economic or beneficial to be used commercially for a profit. Also, many developments merely improved on what already existed.

Aerodynamics and the theories of lift have also not fundamentally changed much since 1947. Thinking has remained dominated by fluid mechanics. Wind tunnels have been replaced by Computerised Fluid Dynamics (CFD), enabled by computers with the software to model airflows.

B. *Flying wings.*

In practical terms, the Newtonian approach supports the development of the flying (blended) wing aircraft designs due to the potential drag and lift efficiency gains. See Fig. 11b.

Fig. 11b. Blended wing designs. [1]

Flying wings appear to be the next logical step in aeronautical development. It is puzzling that the industry is taking so long to realise the technical hurdles and reap the benefits available from flying wings.

This is one of the key areas most overlooked due to the an incorrect understanding of how lift and drag are generated, which has resulted from the wrong approach to aerodynamics and how lift is generated.

C. *Significance of the Newtonian approach.*

Newtonian mechanics based on the mass flow rate (Lift = m/dt * dv) provides a new method to assess how wings produce lift. See Fig. 11c.

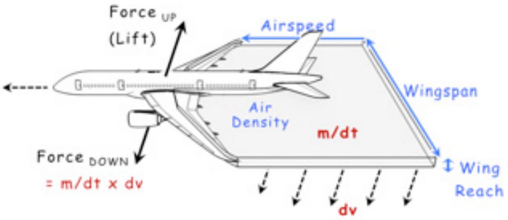

Fig. 11c. Newtonian forces acting on a wing.

This novel approach to lift and flight has not been proposed previously. It provides new and useful insight, including:

- It differentiates between **actively and passively generated forces,** and therefore, the process and direction of the forces generated.
- It identifies that **absolute airflows** is better than relative airflow analysis and wind tunnels to analyse lift.
- **It provides an equation for lift that can be applied universally** to all aircraft, birds, insects, and objects that fly by pushing air downwards.
- Identifies that **wings circulate a large mass of air** in flight.
- There's no evidence that disproves these assertions.
- The argument for lift and buoyancy can be tested by experimentation, and therefore, verified or rejected.
- No other theory of lift provides this depth of analysis of lift that is consistent with all the aspects of flight above. For example, fluid mechanics typically only attempts to explain lift for an airplane in a stable cruise flight.

This new Newtonian approach fundamentally changes the prevailing views held for the last 100 years that fluid dynamics explains lift based on relative wing airflow analysis; and that lift must equal the weight of the aircraft (Lift = Weight) to fly. Previous research appears to have simply overlooked key aspects of how lift is generated by an airplane wing,

D. *Benefits.*

The benefits of the Newtonian approach include:

- Allows **lift** (Lift = m/dt * dv) to be more accurately calculated and analysed by differentiating between 'm/dt' and 'dv'.
- Fewer resources wasted on inaccurate methods used to assess lift, such as fluid mechanics (NS equations).
- Provides a method to calculate the **kinetic energy** used to generate lift, which is shown to be proportional to velocity square of the downwash (K.E. = 0.5 mv^2).
- Provides significant **cost savings** by reducing the amount of trial and error involved in to **aircraft and wing design,** as well as the extensive amounts of **performance testing**

associated with new aircraft. It is possible to more accurately predict wing performance under different conditions (bank angle, AOA, airspeed, ….).

For example, aircraft manufacturers rely on intuition, trial and error to design and build airplanes. [28] They do not use any one theory or equation for lift. This is partly why Boeing's latest airliners (e.g. B-787) look so similar to their previous models (e.g. B-747). Boeing just tries to improve on the designs that they know work.

- **Avoid costly new aircraft failures** of making inefficient aircraft, such as Concorde and the A-380.
- Better assess proposed new technologies, such as supersonic and hypersonic aircraft, wing morphing, flying wings, ….
- **Design a more fuel efficient wing.** Aircraft manufacturers can more easily and accurately assess the most fuel-efficient aspect ratio and flight configuration (e.g. wing AOA, airspeed, …) for wings to generate lift under different conditions and priorities.

  For example, at present airliners fly at a standard cruise speed for an entire flight. However, as aircraft mass varies significantly during flight due to fuel burn, the optimum flight configuration varies a lot during the flight. It may be more efficient to fly at a slower airspeed in the earlier stages of a long haul flight.
- **Improve pilot training and aviation safety** by providing a simple, intuitive, and easily understood explanation for lift and flight. If pilots are taught the correct physics of flight, they are likely to crash.

  A better understanding of how airplanes fly could improve pilot responses to a loss of control in-flight and equipment failure. This could reduce the number of uncontrolled descents into terrain; which remain a significant cause of fatal aviation accidents.
- Provide improved **flight instruments**.

  For example, wing AOA is closely related to both 'm/dt' and 'dv', and therefore, the lift generated (Lift = m/dt * dv). Newtonian mechanics provides the intellectual explanation for flying based on AOA indicators, which provide an improved measure of the lift generated. AOA indicators are already installed in many military airplanes and commercial aircraft, but are not installed in all aircraft.
- **New developments** can be gained by applying the Newtonian approach described in this paper.

  For example, it is proposed that a glider could circumnavigate the globe against the jet stream, by passively re-directing the relative airflow to generate thrust. In addition, this approach could also be applied to generate thrust by boats or air transport vehicles such as rigid airships (blimps).
- Improve the **reputational image** of aeronautical engineers, physicists, and the aviation industry by resolving the debate on the physics of lift and flight, after over one hundred years of heavier-than-air flight.
- The Newtonian approach **solves a variety of enigmas and conundrums**, including:
  - How a wing generates lift.
  - Why lift quadruples if aircraft velocity doubles.
  - How a glider can soar into wind (dynamic soaring).
  - The lift paradox (thrust-to-weight ratios of 0.3).
  - DDWFTTW.
  - d'Alembert's paradox 1752.
- The Newtonian principles for lift can be applied to **other related areas,** where surfaces (airfoils) actively or passively generate a force. For example designing better propellers, rotors, wind turbine blades, and sails.

No serious attempt to resolve this dispute on the causes lift has been made for a very long time. However, after a hundred years of designing and building airplanes, it is reasonable to expect that academics and engineers should have solved the physics by now. Better late than never?

E. Pilots become better aviators.

The Newtonian approach to lift is extremely useful to enable pilots to become better aviators. Pilots are taught a variety of incorrect theories of lift at present.

Aviation authorities (e.g. FAA, CAA, EAA; …) recommend that pilots are taught a theory of flight based on the Venturi effect and Bernoulli's principles of fluid dynamics. NASA describes this and some theories commonly believed to be true as 'incorrect'. [1] In addition, some academics discredited Bernoulli's theorem as an explanation for lift in airplanes at least as early as 1972. [36]

NASA's website states: "There are many explanations for the generation of lift found in encyclopaedias, in basic physics textbooks, and on web sites. Unfortunately, many of the explanations are misleading and incorrect. Theories on the generation of lift have become a source of great controversy and a topic for heated arguments." [1]

Pilots aren't even taught the prevailing view theory of lift based on fluid mechanics, which is used by most engineers and academics. This aspect is partly because fluid mechanics is mathematically complex and difficult to explain in simple terms.

On the other hand, the Newtonian approach to lift is simple and easy to understand. It is also in line with the Newtonian physics advocated by Wolfgang Langeweische in the book: "Stick and Rudder" (1944). [4] This book is famous among pilots for its accurate, practical and common-sense advice on how to fly an airplane.

F. Associated papers.

This paper is an abbreviated version of a more detailed (300+ page) pre-print research paper by the author: "Newton explains lift; Buoyancy explains flight. The physics of how airplanes stay airborne." [2]

12. CONCLUSIONS

A. *Résumé.*

Applying Newtonian mechanics based on absolute airflow analysis and the mass flow rate provides a better explanation for how lift is actively generated by wings, than is currently available. This novel approach has not been proposed previously and provides new and useful insight into the physics of lift.

The new Newtonian explanation allows lift to be better understood and more accurately measured. In turn, it can be used to improve: aircraft and wing design, pilot training, computer simulations, and aviation safety.

The consequent financial and economic benefits could be substantial. For example, better wing design could provide large fuel savings. Less time and resources would be wasted on incorrect theories of lift, which provide sub-optimal solutions. Aircraft that generate lift inefficiently, such as the EUR 25 bn loss from the A-380, could be avoided.

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13. ADDITIONAL INFORMATION

Author: Mr. Nicholas Landell-Mills, independent researcher.

Corresponding email: nicklandell66@gmail.com

Funding: This paper was self-funded by the author.

Project costs: The practical expenses used to write this paper were minimal. These expenses included little more than a computer, internet access, living expenses, and somewhere quiet to work. But to add perspective, the opportunity cost to the author of potential salary forgone in the period that it took to research and write this paper was substantial.

Request for financial support: This paper could not have been produced through the established academic and scientific system. The paper is available for free on the internet. If you found this research to be useful, entertaining or otherwise worthy. Then kindly thank, support, and encourage the author with a financial donation via the email address above on www.PayPal.com or via the direct PayPal link provided here: https://paypal.me/landell66?country.x=FR&locale.x=en_US Thank you.

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The author held a private pilot's license (PPL) for 20 years. He flew and maintained a small, single-engine, home-built airplane (Europa XS monowheel, registration: G-OSJN).

In the eight years 2014–2022, the author worked full-time on applied physics research, including the theory of lift and flight.

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Affiliations: None.

Author Contributions: This paper is entirely the work of the author, Mr. Nicholas Landell-Mills.

Acknowledgements: None.

Disclaimer: All data in the manuscript is authentic, there are no conflicts of interest, and all sources of data used in the paper are identified where possible.

ORCID ID: 0000-0003-4814-0443

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APPENDIX I – UNRESOLVED THEORY OF LIFT

A. The theory of lift remains unresolved.

Fig. I-a. Unknown.

The physics of lift is disputed. There is no scientific experiment on a real aircraft in realistic conditions that proves any theory or equation for lift to be true.

Experts still cannot agree whether aircraft generate lift by being pulled upwards according to fluid mechanics, or pushed upwards according to Newtonian mechanics; nor exactly what role vortices play. This is surprising given airplanes have been flying for over a hundred years.

Academics, engineers, aircraft manufacturers, pilots, aviation authorities, and other pundits (e.g. NASA) promote over twelve diverse theories of lift. New theories are occasionally proposed.

Worse, there is no accepted universal theory of how lift is generated that applies to all objects that fly. Airplanes, helicopters, birds and insects each have their own unique explanations. Different theories are used to explain lift in different insects. This aspect is highly inconsistent.

B. Media and academic commentary.

The media occasionally comment on the on-going debate about the mysterious, unproven and unknown causes of lift:

- "Staying Aloft; What Does Keep Them Up There?" in New York Times, 2003. [24]
- "How Do Airplanes Fly?" in Live Science, 2006. [25]
- "The secret to airplane flight. No one really knows." in the National Newspaper, 2012. [26]
- "There's No One Way to Explain How Flying Works," in Wired Magazine, 2018. [27]
- "No One Can Explain Why Planes Stay in the Air." in the Scientific American magazine, 2020. [28]

Academic journals occasionally address this issue as well:

- "Quest for an Improved Explanation of Lift," in the AIAA journal, 2012. [29];

The physics on how birds fly is also debated:

- "….to date, flapping flight is not fully understood." [30]
- "….there are still myriad open questions about how animals fly with flapping wings," [31]

C. Academics, engineers, pilots, pundits, …..

Various groups promote at least twelve radically different theories of flight, which include:

- **Academics and engineers** prefer complex models based on **fluid mechanics** (e.g. Bernoulli, Navier-Stokes, Euler, ….). They frequently confuse mathematical proof, wind tunnel experiments or computer simulations (e.g. CFD) for scientific evidence.
- **Aircraft manufacturers and designers** (e.g. **Burt** Rutand) design wings by **intuition, trial and error,** rather than by any particular theory or equation for lift. [28][33][34][35] This aspect is evident from the long list of failed wing designs as well as the unresolved debate on how wing design affects lift performance.

  Similarly, micro unmanned vehicles (drones) are simply built to **mimic bird and insect flight**, without the designers fully understanding the physics involved.
- **Pilots** prefer **Newtonian based theories of lift.** Simply put, wings push air downwards and the reactive equal and opposite force pushes the airplane upwards. Momentum is transferred from the airplane to the air.
- **NASA** sits on the fence in this debate, and supports both explanations of lift. "So **both Bernoulli and Newton are correct**." [1] NASA fails to state what proportion of lift is explained by Bernoulli and Newton; 50/50? Or 70/30?

  However, both Newtonian and fluid mechanics cannot be true as they provide very different and incompatible explanations of lift. How can NASA not know which theory of flight is correct?
- **Aviation authorities** (e.g. FAA, CAA, EAA; …) recommend that pilots are taught a theory of flight based on the **Venturi effect and Bernoulli's principles** of fluid dynamics. NASA describes this theory to be incorrect' [1] and academics discredited Bernoulli's theorem as an explanation for lift at least as early as 1972. [36]
- **Other groups** promote a mixture of different theories of lift based on vortices, the Magnus effect, the Coanda effect, …..
- Some group advocate that the **pressure differential** on a wing explains lift. However, pressure is a consequence of a force (Pressure = Force/Area), not a cause. Correlation of pressure and lift on a wing does not prove causality.
- **Empirical observation:** The **factors** that affect lift in practice have been observed and measured; as summarized by the standard equation for lift: [1]

$$\text{Lift} = 0.5\,(\text{Aircraft Velocity}^2 * \text{Air Density} * \text{Wing Area} * \text{Lift Coefficient})$$

However, this equation only describes the factors that affect lift; it does not explain why these factors affect lift.

In particular, fluid mechanics fails to explain the physics of the standard equation for lift, but Newtonian mechanics can. For example, only Newtonian mechanics can explain why lift quadruples if aircraft velocity doubles.

APPENDIX II – DEFINITIONS

A. Abbreviations for aircraft.

- A-380 – Airbus 380
- A-320 – Airbus 320
- B-787 – Boeing 787
- B-747 – Boeing 747

B. Abbreviations and definitions of terms.

- AOA – Angle-of-Attack.
- Aspect ratio. Wingspan divided by wing depth (chord). See Fig. II-b-i.

$$Aspect\ Ratio = \frac{wingspan}{mean\ wing\ depth\ (chord)}$$

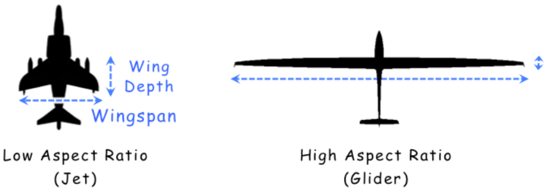

Fig. II-b-i. Aircraft with different wing aspect ratios.

- Chord – Wing depth.
- Engine Thrust − The force generated by the propeller of jet engines by accelerating air backwards, to create backwash and a backward force.
- Flight – when the aircraft or object is airborne (flying).
- The glide ratio is the horizontal distance travelled divided by the vertical distance (altitude) lost an unpowered downward glide, as shown by the equation:

  Glide ratio = Horizontal / Vertical distance
- Gravity – A force towards the ground (or centre of the earth) equal to 9.8 m/s^2 [1].
- Lift − Vertical force pushing the airplane up against gravity; in the direction away from the ground.
- Lift v. Flight. Lift is a force that pushes an aircraft up against gravity. Whereas flight describes the conditions when lift is sufficient for an aircraft to be airborne. It is important to note that an aircraft can generate lift but not fly.
- MTOW – Maximum Take-Off Weight
- STOL – Short Take-Off and Landing.
- Thrust-to-weight ratio – The maximum engine thrust divided by the aircraft's maximum take-off weight (MTOW).

  i.e. Maximum Engine Thrust / MTOW
- Thrust – Engine thrust.
- Weight − Mass multiplied by gravity. [1]

  i.e. Weight = Mas * Gravity (9.8 m/s^2)
- Wing reach = This is a new term that includes the vertical distance facing the direction of travel that the wing influences the air. See Fig. II-b-ii.

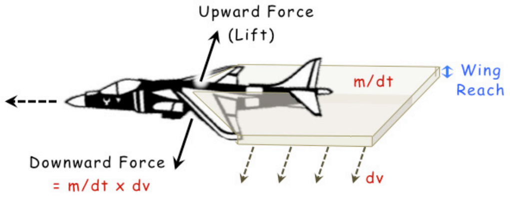

Fig. II-b-ii. Wing reach diagram.

Wing reach includes the air that the wing directly pushes out of its path due to the volume of space that the wing passes through. Therefore, wing reach depends on:

- Airfoil's thickness.
- Wing AOA.
- The air above and below the wing that is directly affected by the wing's path through the air.

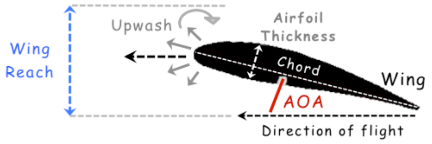

Fig. II-b-ii. Wing reach in a wing cross-section.

Wing reach does not include the air indirectly affected by the wing, which is the air displaced by the air that the wing directly flies through.

Wing reach is a key assumption in the calculation of the air flown through each second (m/dt) by a wing. The greater the wing reach, the greater the 'm/dt', and therefore, the greater the lift generated (Lift = m/dt * dv).

- Wingspan loading. – The amount of aircraft mass (kg) supported by 1 meter of wingspan. This is a similar concept to wing loading, but different. Wingspan loading is a new concept that arises due to the method in which Newtonian mechanics calculates lift (Lift = m/dt * dv).

$$Wingspan\ Loading\ (kg/m) = \frac{Aircraft\ Mass\ \ (kg)}{Wingspan\ (m)}$$

$$Wing\ Loading\ (kg/m^2) = \frac{Aircraft\ Mass\ \ (kg)}{Wing\ Area\ (m^2)}$$