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Principles of Flight

Principles of Flight

Learning Outcome 1:

Know the principles of lift, weight, thrust and drag
and how a balance of forces affects an
aeroplane in flight

Part 1



Lift and Weight

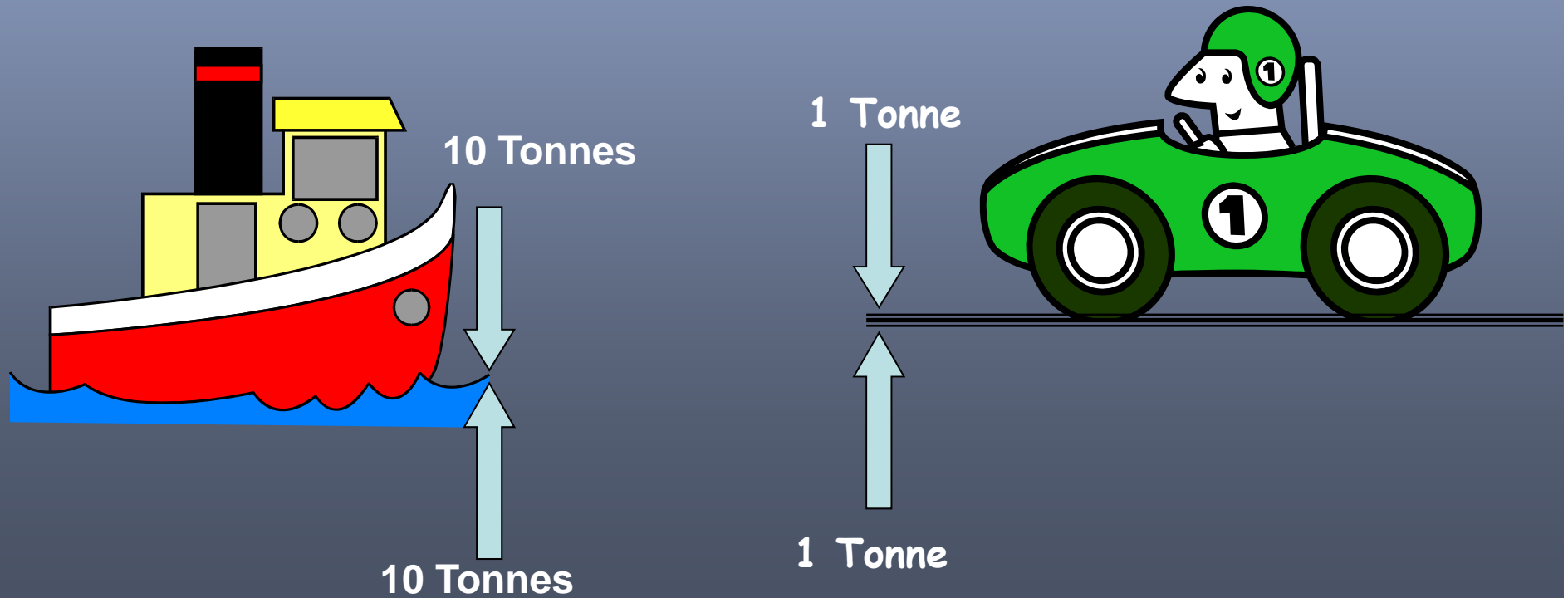
Objectives:

1. State Newton's Third Law.
2. Explain Weight and Lift for Straight and Level Flight.
3. Describe Bernoulli's Principle.
4. Explain how an aerofoil affects airflow and produces lift.
5. Have a knowledge of simple aerodynamic terms.
6. Identify and define parts of an aerofoil cross-section.
7. Describe how Airspeed, Angle of Attack, Air Density, Wing Shape and Area affect Lift.

Lift and Weight

Sir Isaac Newton's 3rd Law?

“To every **Action** there is an **Equal** and **Opposite** Reaction”



Air

What is Air?

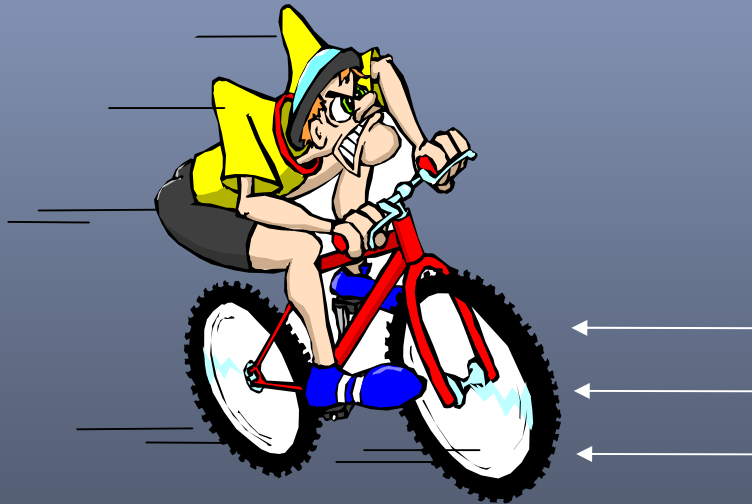
Can we feel it?

Can we see it?

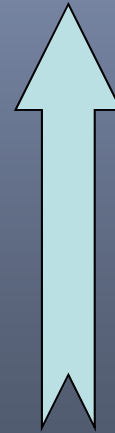
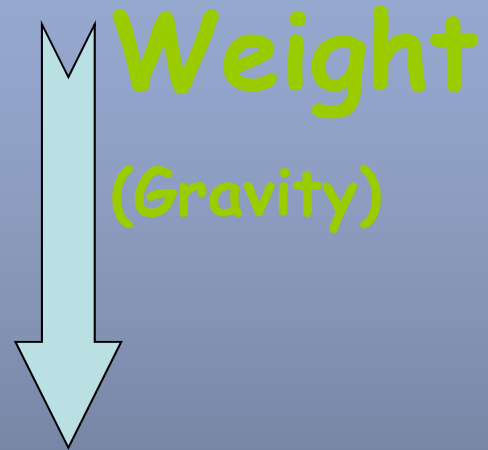
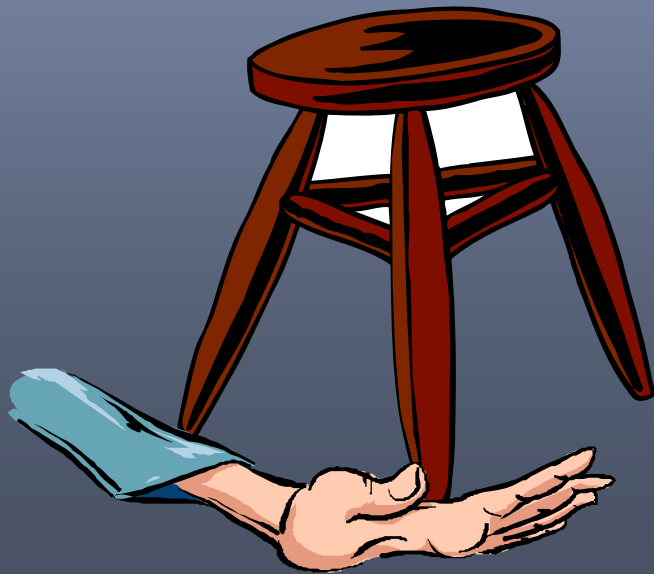
What is it doing?



Moving Objects Through the Air

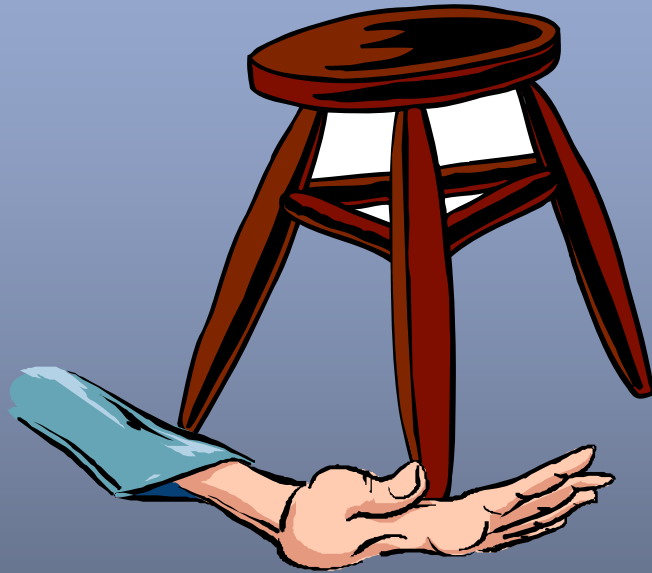


Weight



Lift

Weight



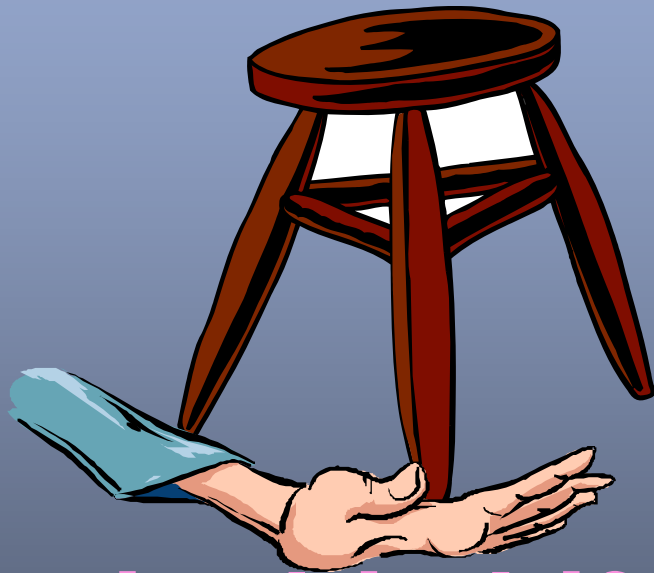
Weight
(Gravity)



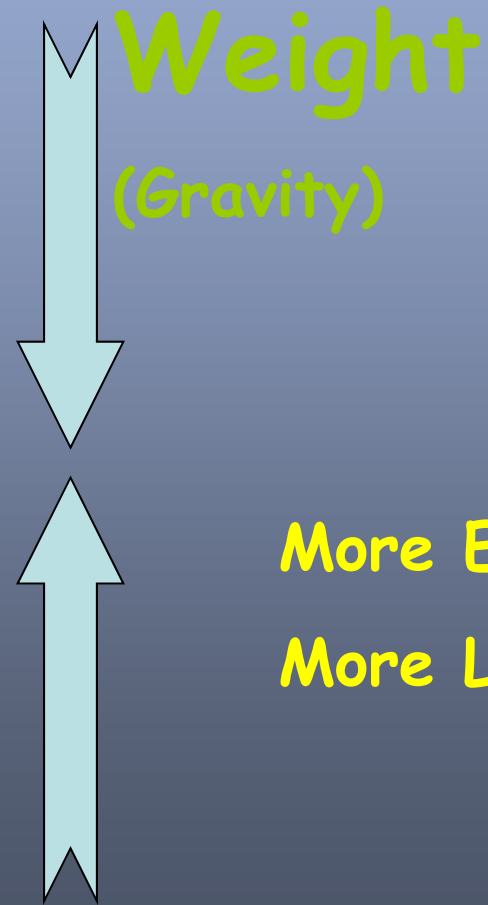
Less Effort =
Less Lift!

Lift

Weight

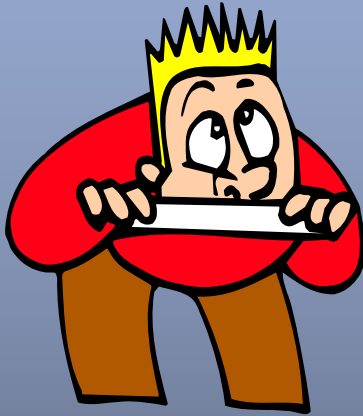


How is this Lifting
Force given to an
Aircraft?



Lift

Lift



Work in pairs:

Hold 2 sheets of A4 paper, about a finger's width apart .

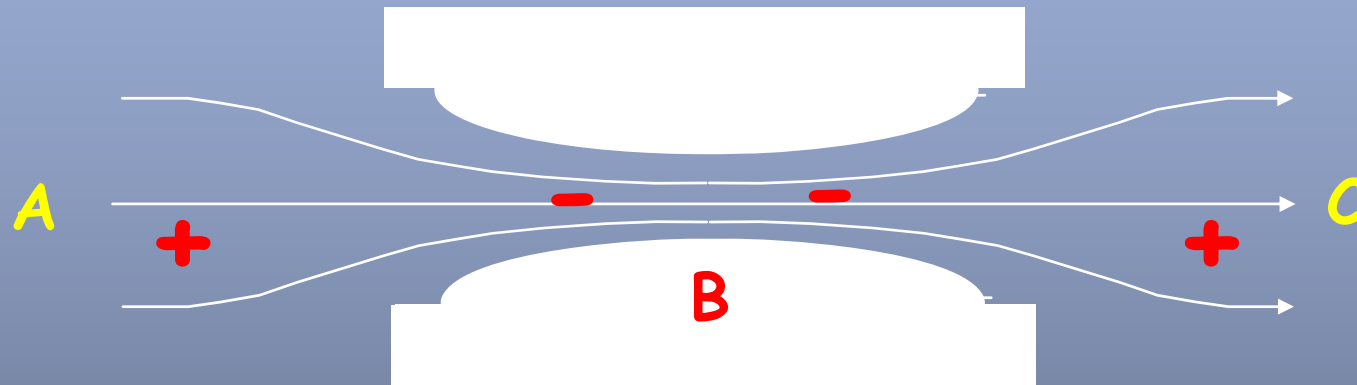
Blow hard down the gap.

Now!
Your turn to do some work!
WHAT HAPPENS?

Did they separate or come together?

Why does a slightly open door close when a draught blows through the gap, rather than open?

Lift – Wind Tunnel Tests



Air enters at 'A'.

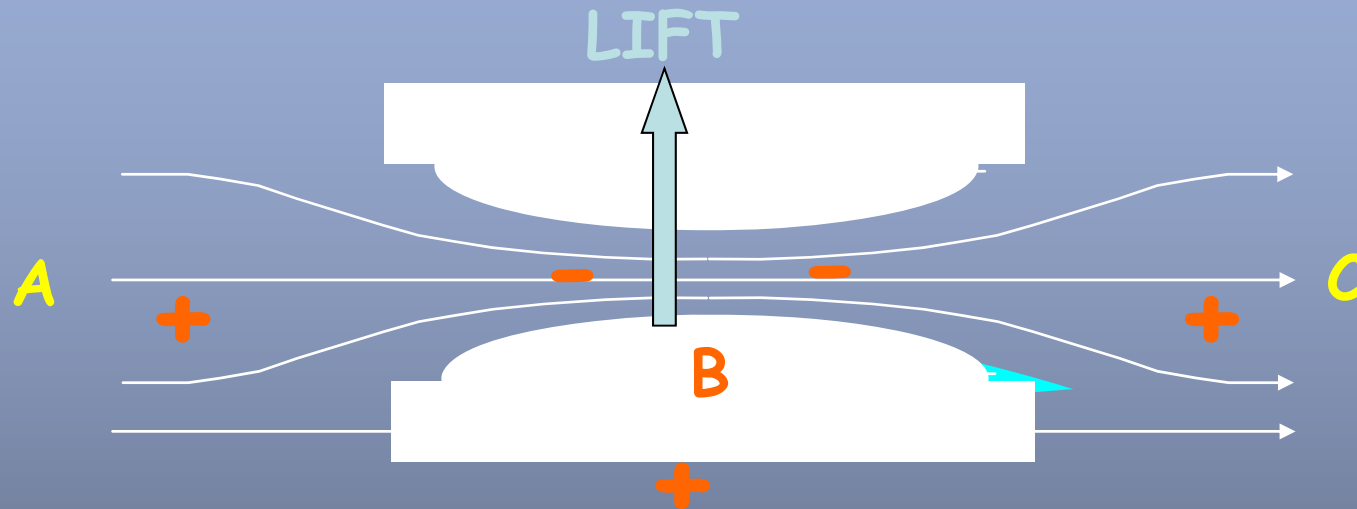
On reaching 'B' it has increased in speed to get through the narrower gap.

At 'C' the air has returned to the same values as 'A'.

If Speed increases then Pressure Drops & Vice Versa.

SO, HOW DOES THIS WORK AS A WING?

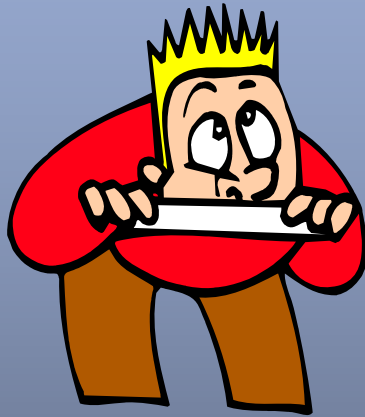
Lift – Wind Tunnel Tests



A Wing works in the same way as the “Wind-Tunnel”.
Because the air is faster over the top surface, then
the pressure is decreased.

The Wing is now producing LIFT.

Lift



NOW!

Your turn to do some
What happens when we blow over
more work!
a sheet of paper?

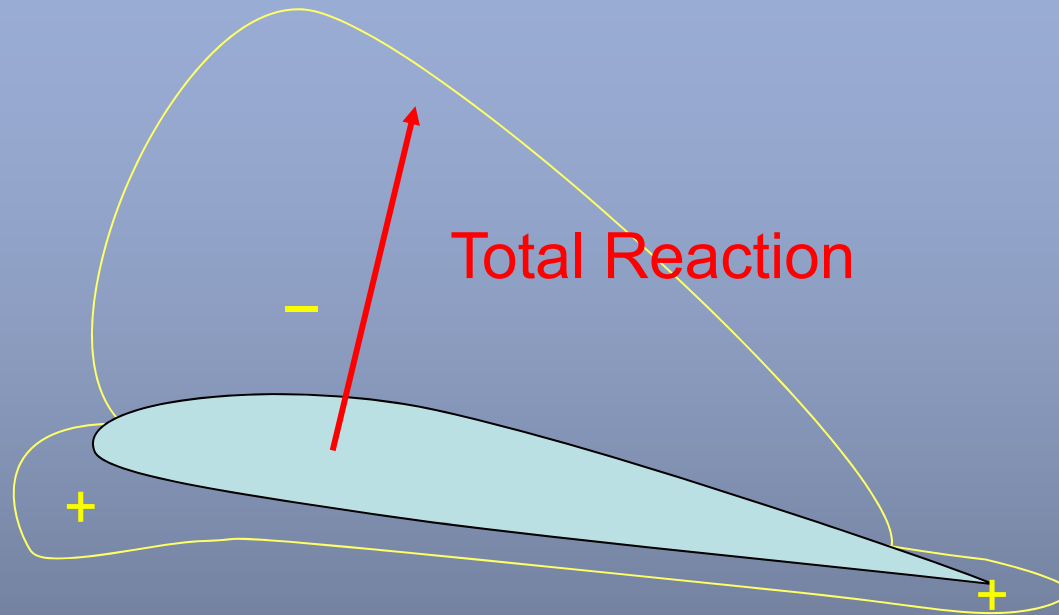
This is Daniel Bernoulli's Theory



DEFINITIONS



DEFINITIONS



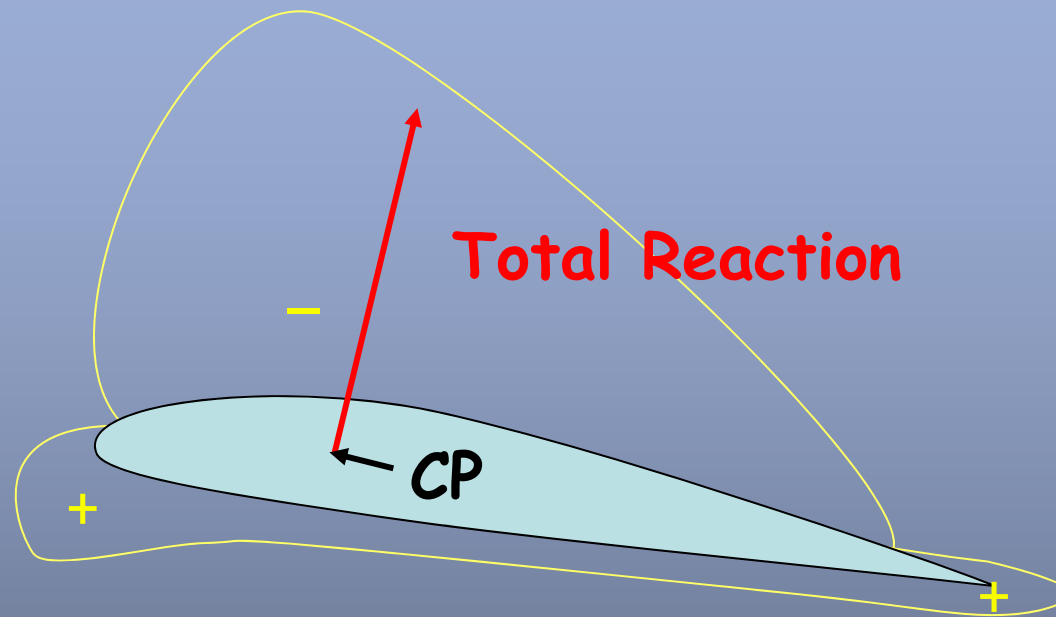
PRESSURE ENVELOPE

The line showing the magnitude of the static pressure above or below ambient.

TOTAL REACTION (TR)

The 'resultant' of all the aerodynamic forces, usually on the airfoil only (as in the above illustration).

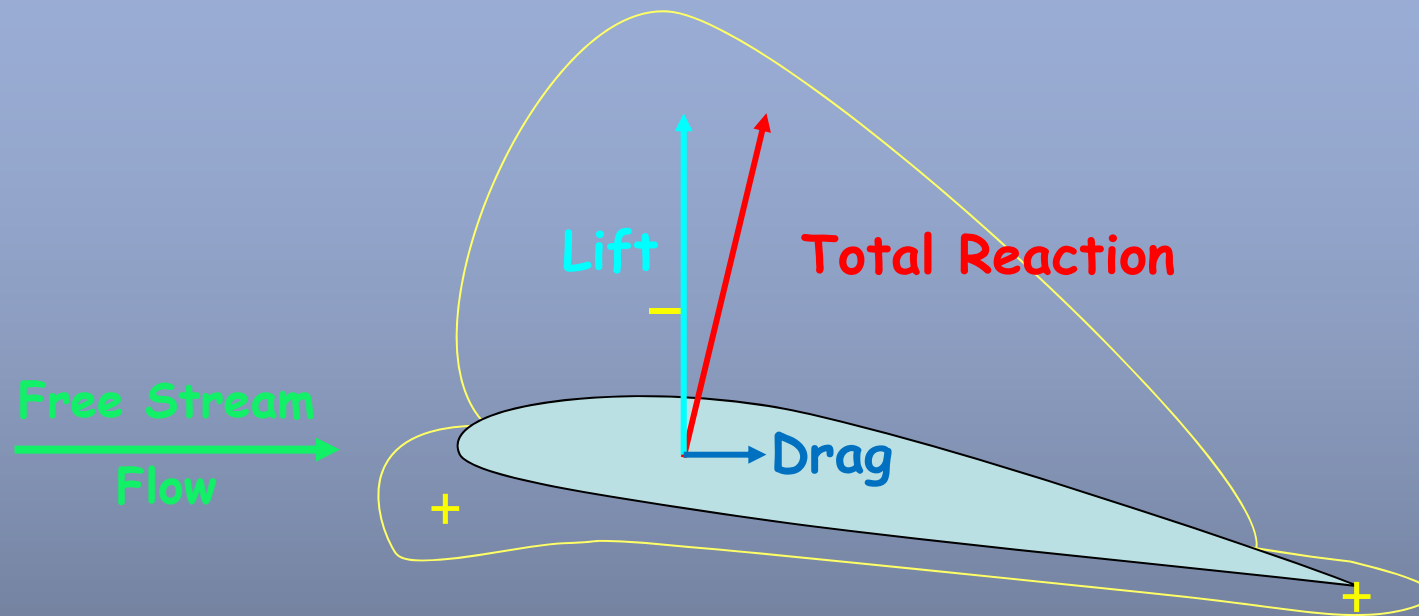
DEFINITIONS



CENTRE OF PRESSURE

The point at which the total reaction is assumed to act.

DEFINITIONS



LIFT

The component of the total reaction which is 'perpendicular' to the free stream flow (and therefore perpendicular to the flight path)

DRAG

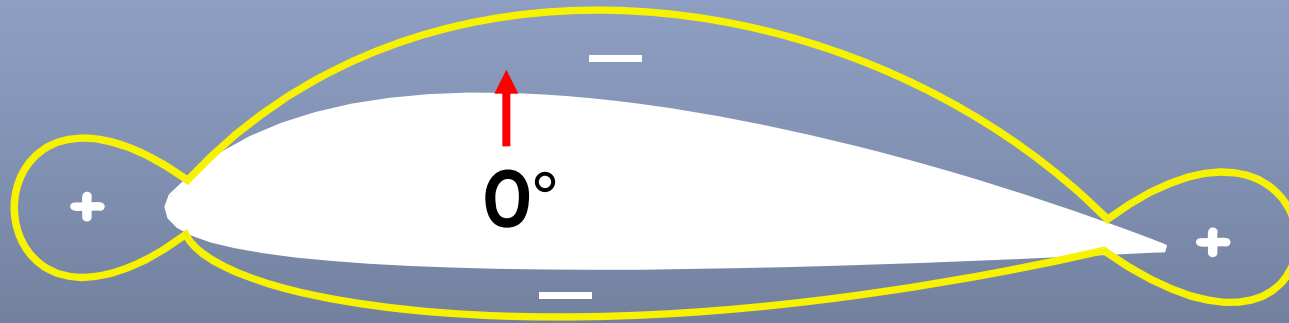
The component of the total reaction which is 'parallel' to the free stream flow (and therefore parallel to the flight path)

More Later!



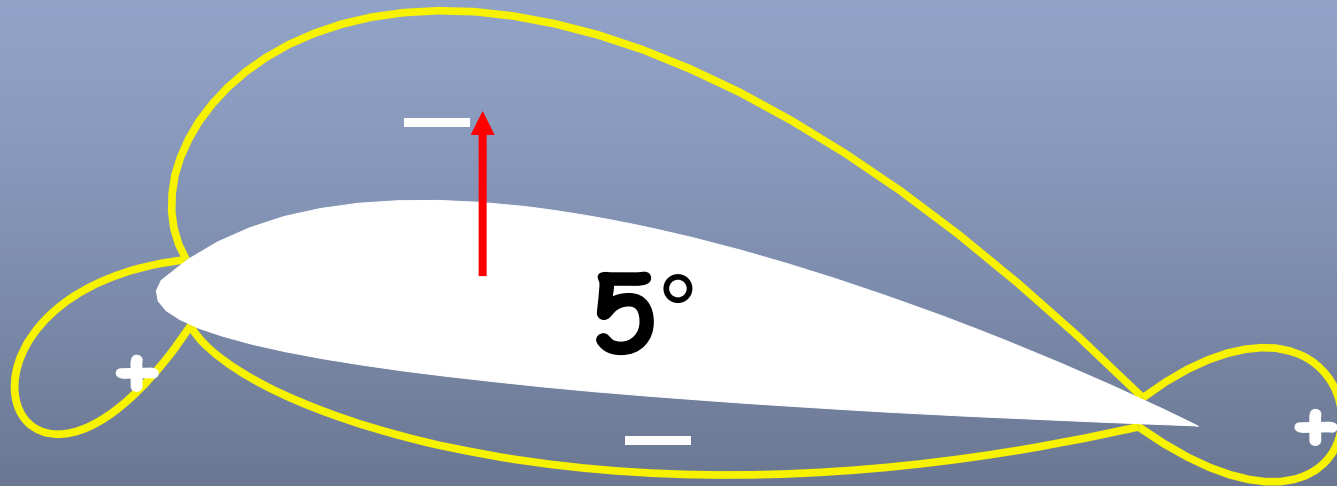
Distribution of Lift

Pressure Envelope at 0°



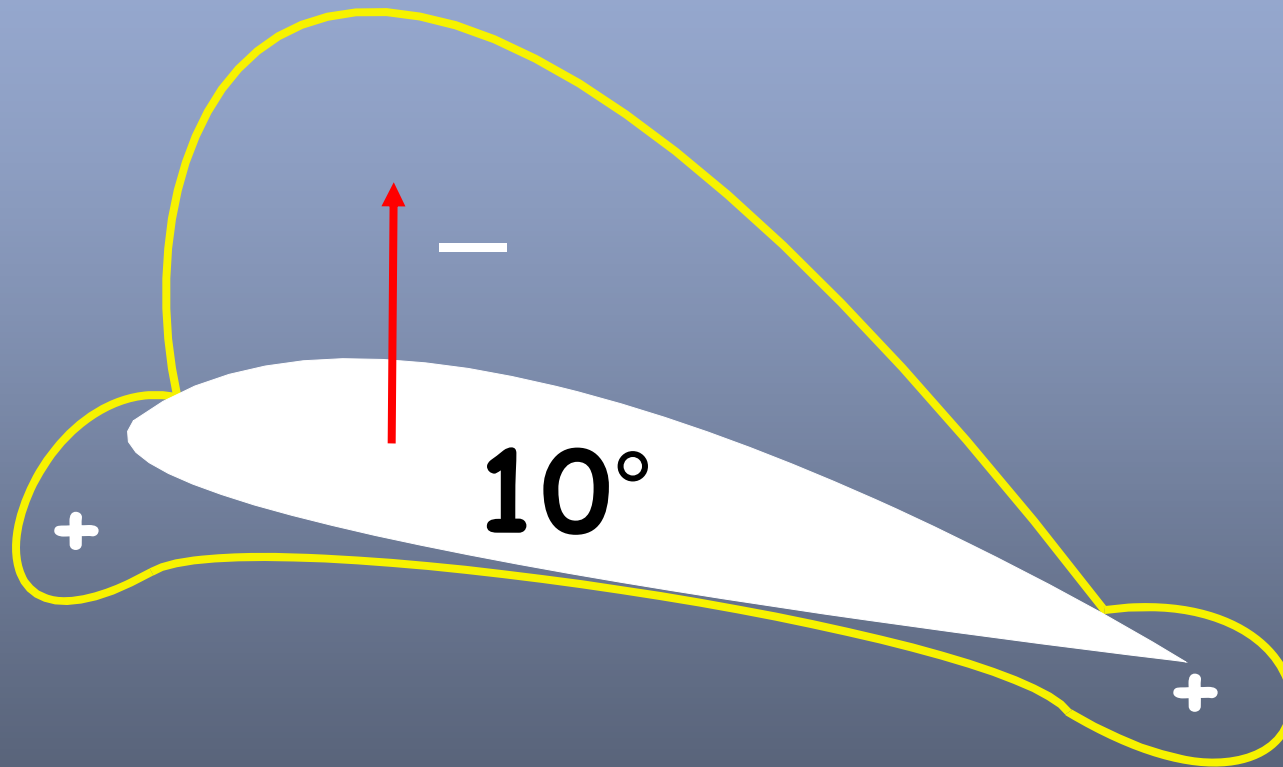
Lift - A Little

Pressure Envelope at 5°



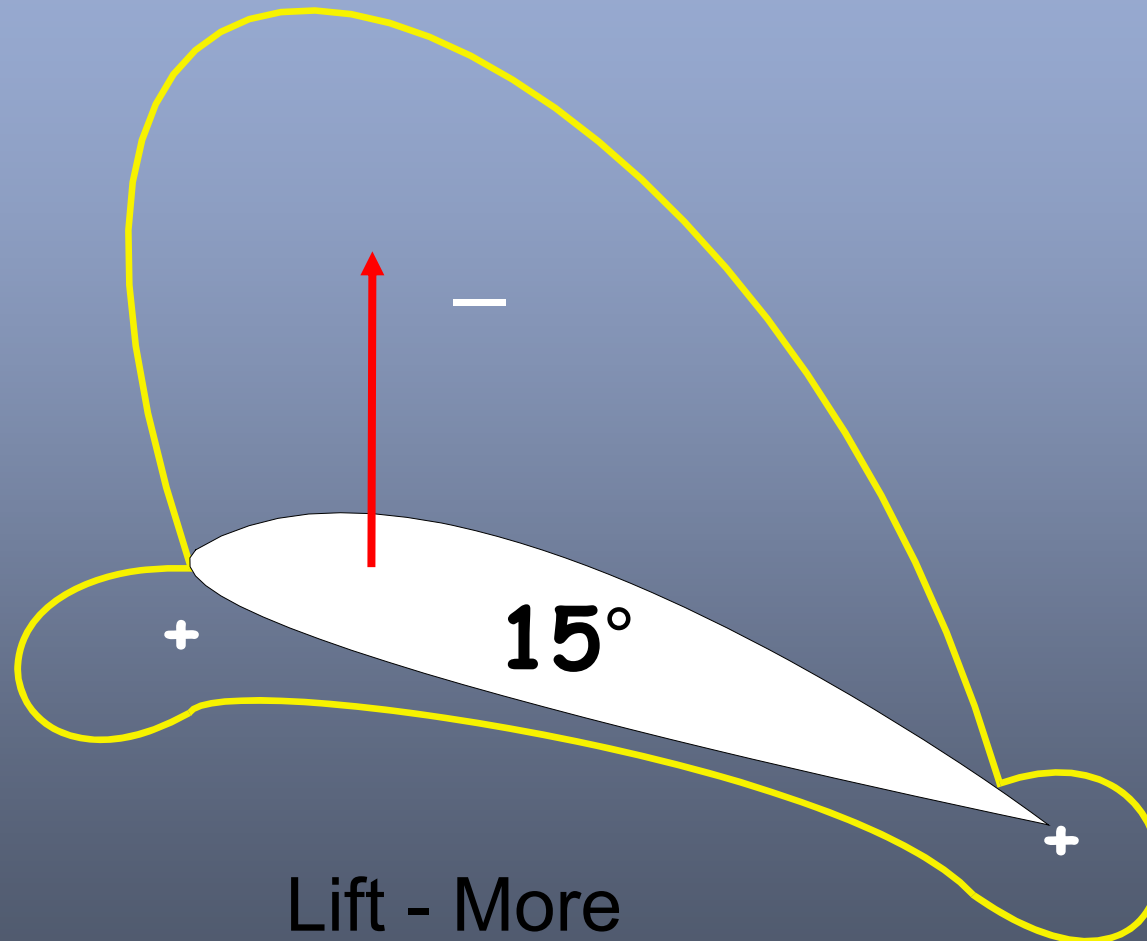
Lift - More

Pressure Envelope at 10°



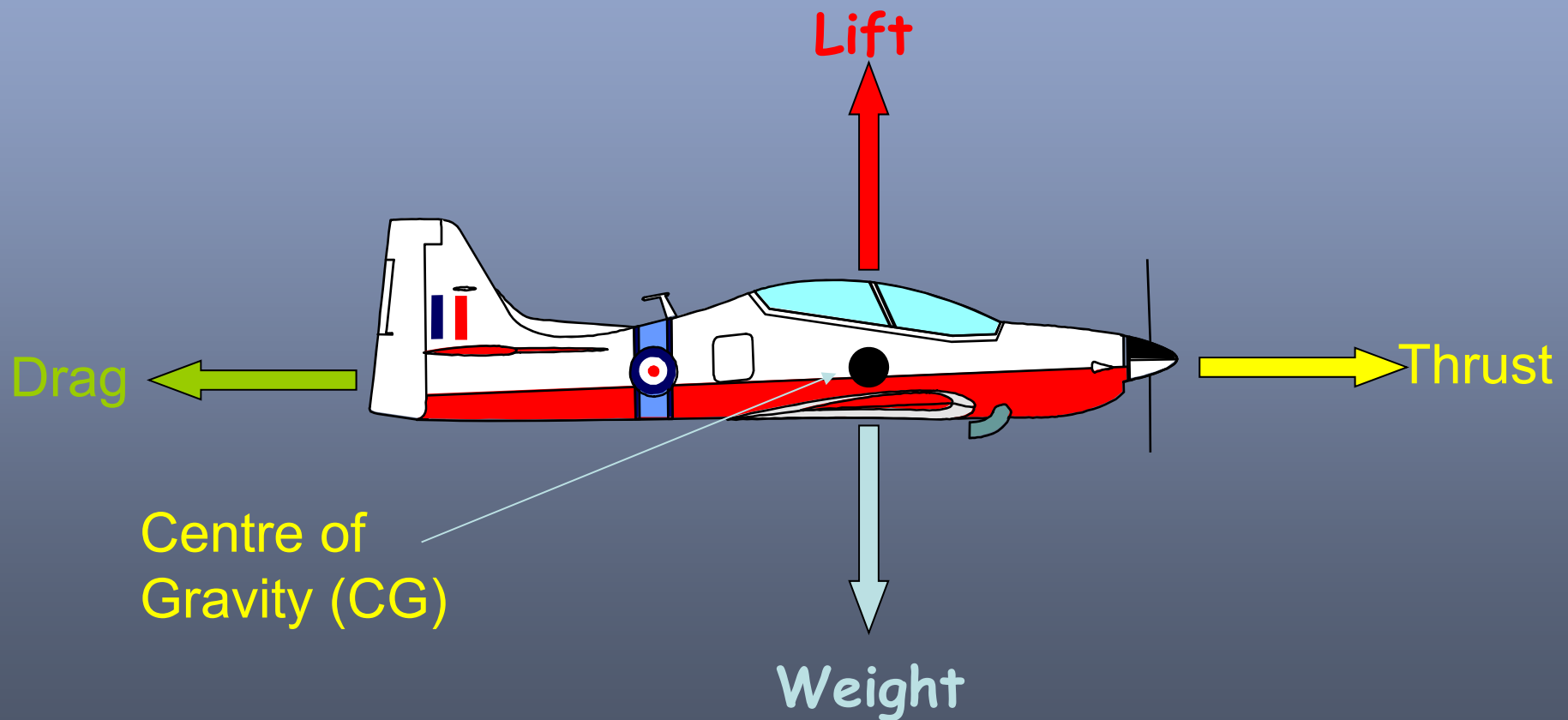
Lift - More

Pressure Envelope at 15°



Straight & Level Flight

What Forces are affecting the Aircraft?



Which of these forces is balanced by the other three? & Level Flight?

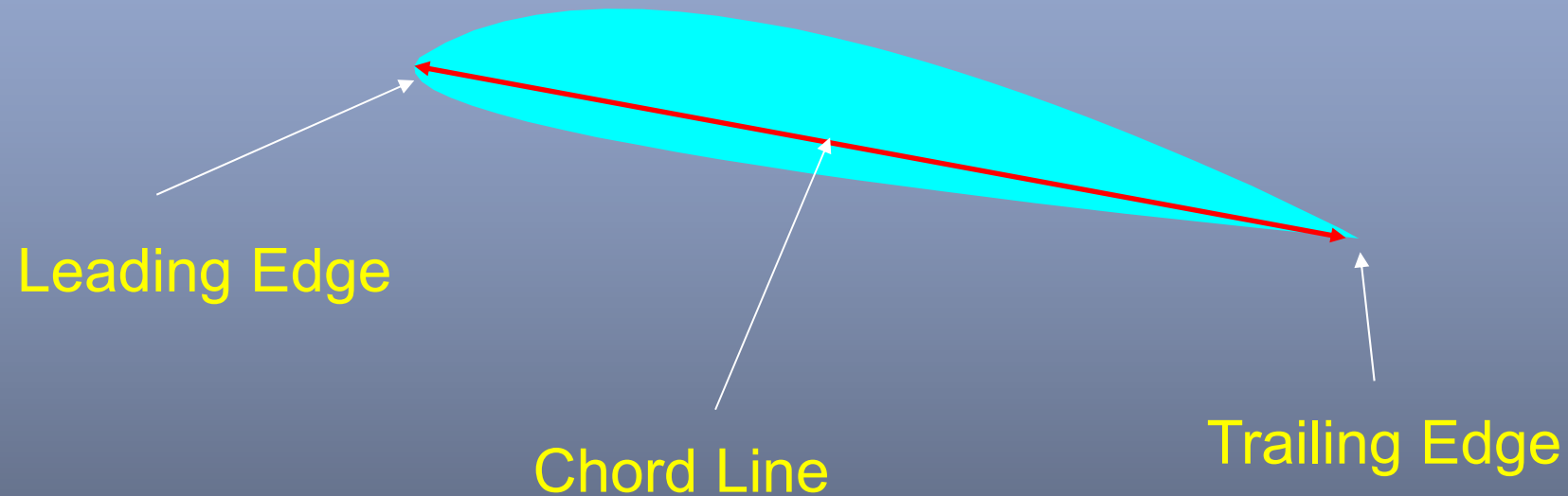
Some More Definitions

Leading Edge

Trailing Edge

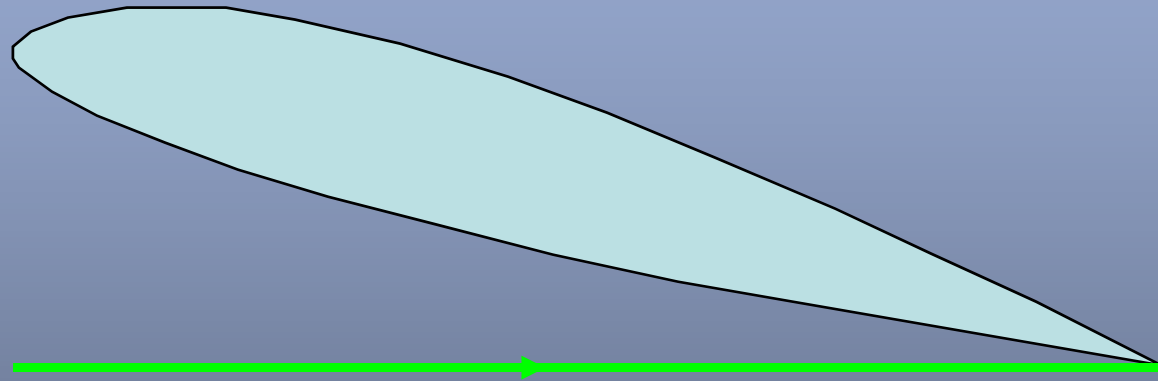


Some More Definitions



The straight line passing through the Centres of Curvature of the Leading and Trailing Edges of an Aerofoil.

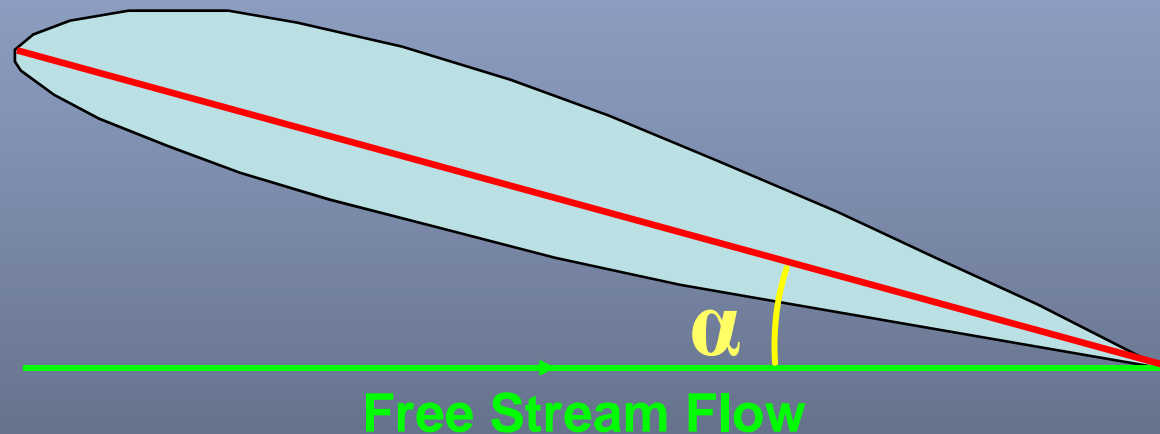
DEFINITIONS



FREE STREAM FLOW (*Relative Airflow*)

The Airflow remote from the Aircraft, and unaffected by its presence. Sometimes called the Relative Airflow.

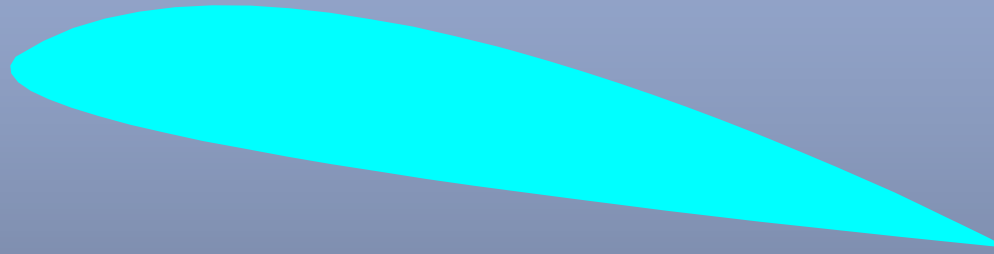
DEFINITIONS



ANGLE OF ATTACK *Symbol α (alpha)*

The Angle between the Chord Line and the Free Stream Flow.

DEFINITIONS



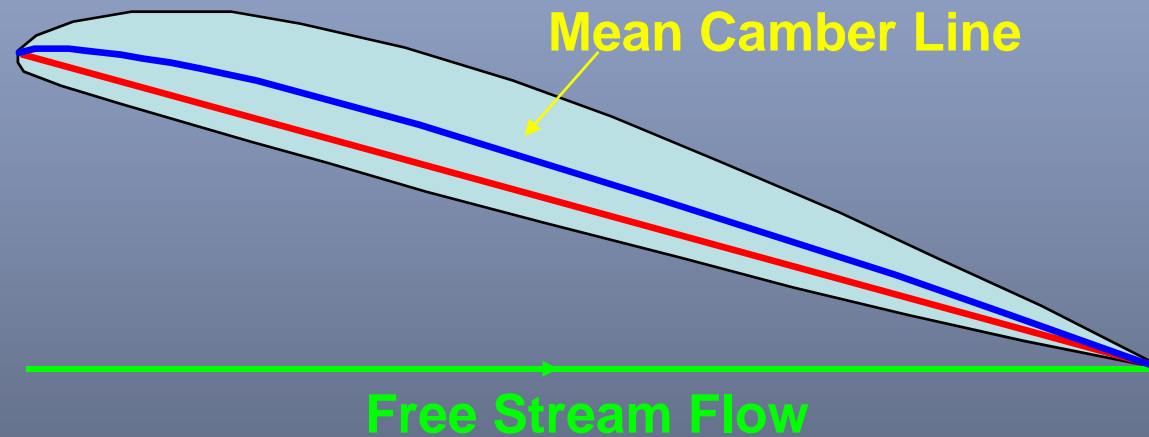
CAMBERED AEROFOIL

A general purpose aerofoil with a large “curved” surface.

Large Camber = More Lift

But, what wing shape do fighter aircraft have?

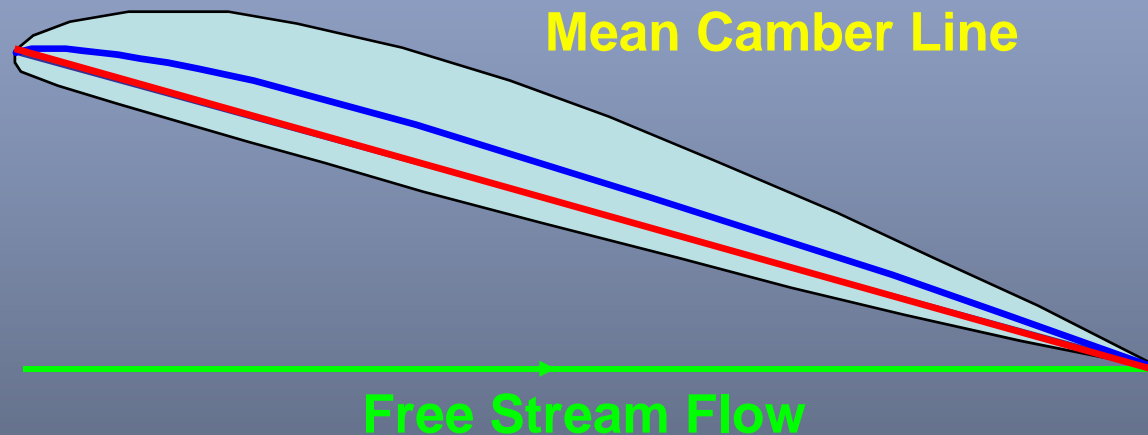
DEFINITIONS



MEAN CAMBER LINE

The line 'equidistant' from the upper and lower surfaces of the airfoil section.

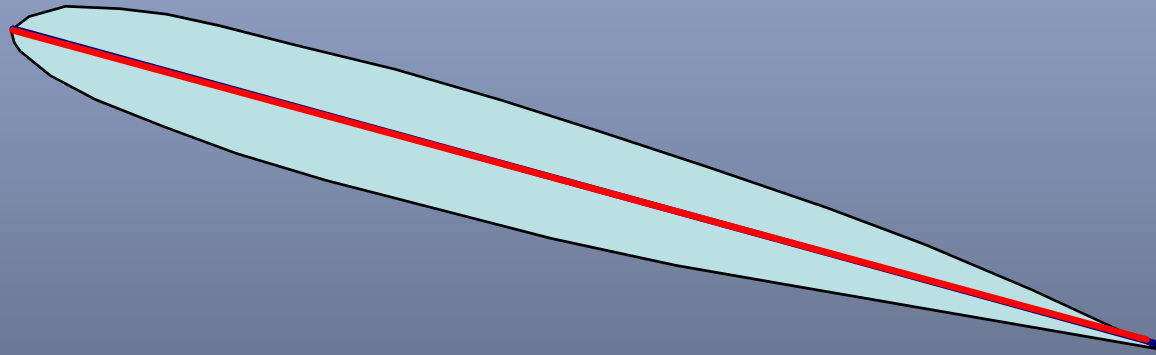
DEFINITIONS



CAMBERED AEROFOIL

If the mean camber line lies above the chord line (as in the above illustration) the aerofoil section has 'positive camber'; it is a cambered aerofoil.

DEFINITIONS

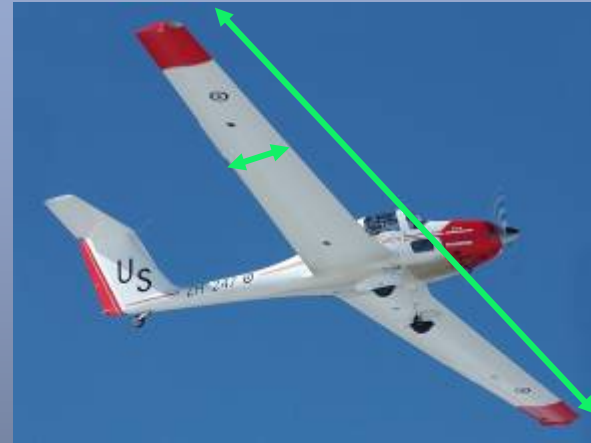


SYMMETRICAL AEROFOIL

If the mean camber line is 'co-incident' with the chord line it is a symmetrical aerofoil section

Wing Shape & Area

Low aspect ratio 2.4:1



High aspect ratio 16:1

ASPECT RATIO

The ratio of : $\frac{\text{wing span}}{\text{mean chord}}$ or $\frac{\text{wing span}^2}{\text{wing area}}$

Factors Affecting Lift

Factors Already Discussed:

- Angle of Attack.
- Wing Shape – Camber.
- Wing Area.

Additional Factors:

- Air Density.
- Airspeed.



Lift Formula

When all of the 'variables' are put together we can derive a formula for lift:

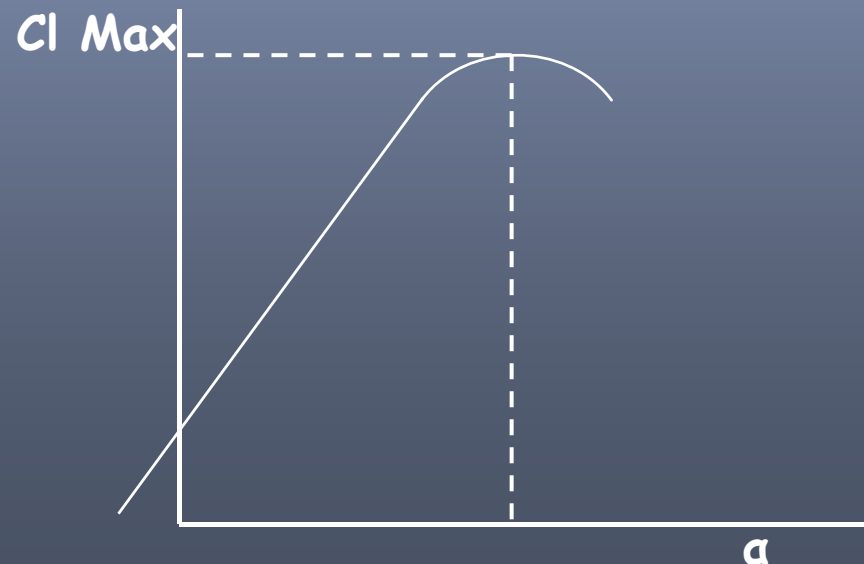
$$\text{Lift} = C_L \frac{1}{2} \rho V^2 S$$

C_L = Coefficient of Lift

ρ = Density (rho)

V = True Airspeed

S = Surface Area





Any Questions?



Cabo
the next generation

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Questions

Newton's 3rd Law States:

a. Every object has weight.

b. Weight equals lift during flight.

c. Every action has an equal and opposite reaction.

d. Every force causes an object to move.



Questions

In which direction does LIFT operate relative to airflow?

a. Parallel to it.

b. Perpendicular (at 90°) to it.

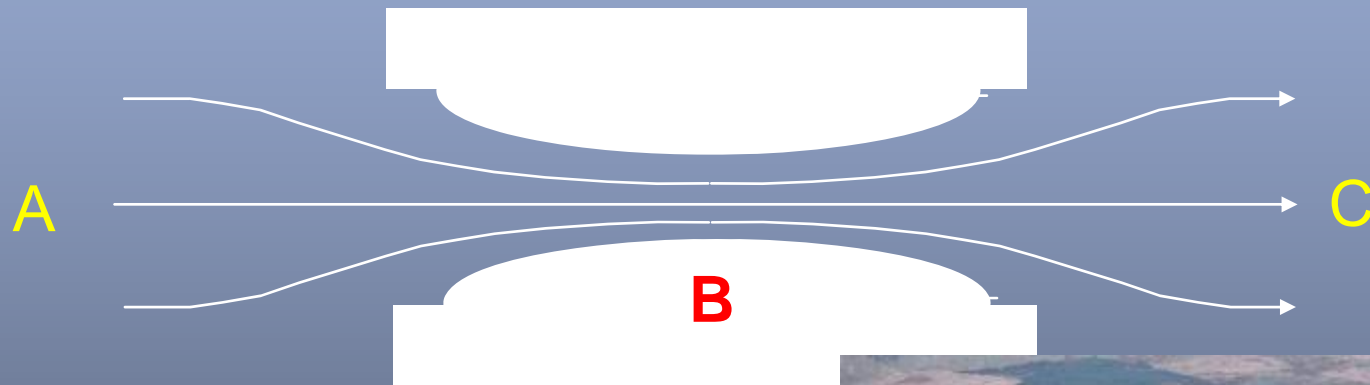
c. Straight up.

d. Straight down.



Questions

What has happened to the air pressure at point 'B'?



- a. It is greater than at point 'A'.
- b. It is greater than at point 'C'.
- c. It is the same as point 'C'.
- d. It is lower than at point 'A'.



