What goes up might come down: Bernoulli

Unit 2 study 3.4

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Going Up in the 18th Century

- Politics, Sex and Science
  - The renaissance brought to Europe the concept of personal advancement through achievement in science.
  - Those poised to make (or steal) grand discoveries were greeted with immense prestige and reward.
  - The race was to publish first.

The case of Bernoulli vs Newton

- The "Bernoulli" position that lift is generated by a pressure difference across the wing
- The "Newton" position that lift is the reaction force (Newton's 3rd Law) on a body caused by deflecting the flow of air.

The protagonists

- Newton (1642-1727) published is findings on motion and forces around 1687.
- Bernoulli (1700-1782) Investigated blood flow through the arteries and modelled these with pipes. Published 1738.

Bernoulli?

- Bernoulli never attempted to explain the aerodynamic lift of an object.
- *Neither did Newton*

Forces on an Aeroplane

- Lift from the wing & tail
- Weight a function of mass and gravity
  (Newton pops up his head here)
- Thrust from the propulsion system
- Drag due to the skin friction of the surface of the aeroplane with the air AND the profile drag or shape of the aeroplane

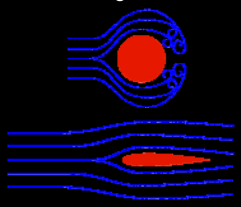
Drag

Skin friction is a function of the surface area wetted by the air stream.

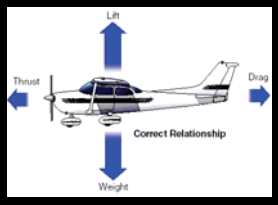
Any increase in surface area will increase skin friction drag.

Skin friction drag is affected by the fluid's speed and viscosity (stickiness of air)

- Profile drag is the resistance due to the shape of the aeroplane disturbing the air.

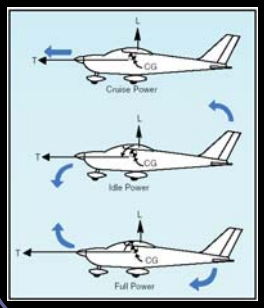


Flight at Constant height & Velcoity



- Equilibrium
- For level flight
  - Lift = Weight
- For constant velocity
- Thrust = Drag
- Newton's 3rd Law

Equilibrium Torque and Moments

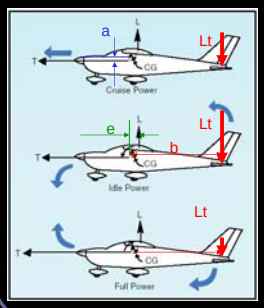


- What happens if the engine is not in line with the Drag force?

But!

- For an airplane to be stable.
- So……!

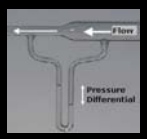
Level Flight



- What happens if the engine is not in line with the Drag force?
- As the pilot changes thrust (power) the airplane wants to pitch
- Newton's 3rd Law
- The moment due to the tailplane must equal
  - **bLt = aT - eL**

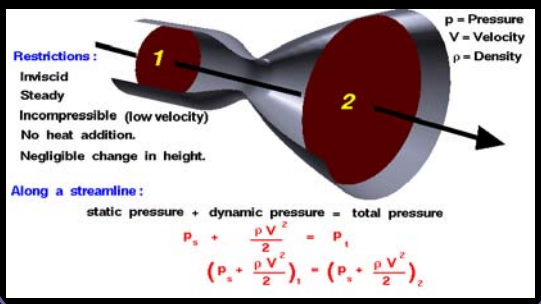
Bernoulli's Equation

- Bernoulli wanted to understand blood flow through the human body

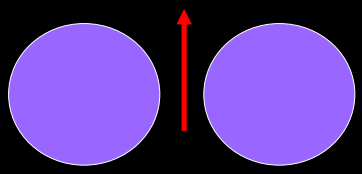


- **The mathematical statement of this energy conservation is stated in the BERNOULLI EQUATION:**
- ***P1 + ½ρv12 = P2 + ½ρv22***

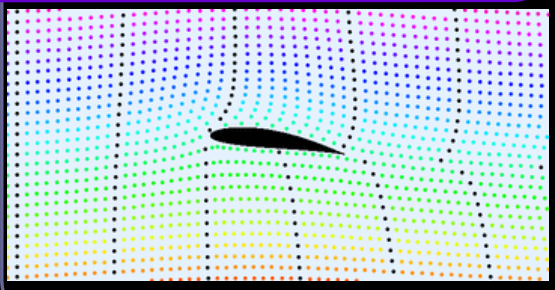
Can we prove this?



Experiment 1



Does Bernoulli work?

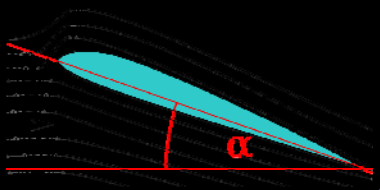


What did we see?

- **The air travels a greater distance over the top of the wing.**
- **Therefore must travel faster.**
- **Therefore produces lower pressure.**
- **Therefore pressure difference produces a lift force.**
- **Score 1 for Bernoulli**

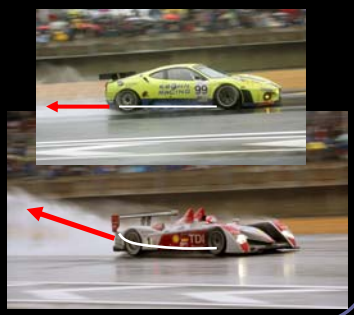
Aerofoils

- As we have just seen an aerofoil work at an angle to produce lift



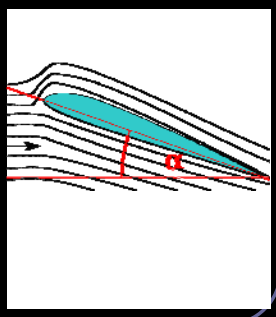
Newtons Third Law

- The yellow car a flat bottom
- The red racing car has a aerofoil shaped under body
- Observe the water spray angle
- The red car generates 1 tonne of down force the yellow zero down force both at 210 kph.
- Newton is right!



Results

- What did we observe?
- Leaves blown by downwash of air
- The resulting upward reaction
- Score 1 to Newton
- Newton's third law that for every action there is an equal and opposite reaction works for aerofoils
- It's a Draw



Flight Tests

- Glide Slope
- Research Question
- Is the best glide angle of a glider change with change in payload (glider weight)?
- Is the velocity of the air realy faster over the top of a wing?

Bernoulli verses Bernoulli

- In 1734, Daniel Bernoulli submitted an entry for the Grand Prize of the Paris Academy giving an application of his ideas to astronomy. His father also entered the competition being a famous scientist in his own right.
- Daniel and his father were declared joint winners of the Grand Prize.
- As a result, his father was furious to think that his son was considered his equal, and banned Daniel forever from his house.

Newton verses Hooke

- Robert Hooke (1635-1703) famous for Hooke's law on elasticity and the definition of what we call a cell to define microbe creatures. He published a partial work on gravitation ten years before Newton.
- Intense rivalry ensured between Hooke and Newton.
- Scandalous stories of Hooke's formerly discrete taste for young ladies (his "nieces"") mysteriously became public knowledge (believed to have cost him a knighthood).
- When Newton (1642-1727) became president of the Royal Society Hooke's portrait disappeared from the Society never to be found.

Postscript

- Daniel Bernoulli did produce other excellent scientific work during these many years back in Basel. In total he won the Grand Prize of the Paris Academy 10 times, for topics in astronomy and nautical topics. He won in 1737 for work on the best shape for a ship anchor; 1740 for work on Newton's theory of the tides; in 1743 and 1746 for essays on magnetism; in 1747 for a method to determine time at sea; in 1751 for an essay on ocean currents; in 1753 for the effects of forces on ships; and in 1757 for proposals to reduce the pitching and tossing of a ship in high seas.
- Daniel Bernoulli and Sir Isaac Newton never met.

Unit Outline

Key knowledge
To achieve this outcome the student should be able to:
• apply the concepts of forces, torques and equilibrium to balancing an aircraft, including reference to Newton's laws of motion;
• explain lift in terms of Bernoulli's principle and the rate of change of momentum;
• model lift and Bernoulli's principle using a wind tunnel;
• explain drag, skin friction drag, pressure drag and principles of thrust;
• investigate experimentally the relationship between power and thrust;
• analyse aircraft performance including takeoff, climb, descent and cruise, with reference to Newton's
laws of motion and Bernoulli's principle;
• investigate experimentally identified aspects of performance using a model;
• analyse risks in the use and testing of flying models using relevant data;
• identify and apply safe and responsible practices when using and testing flying models.