L 15 Fluids - 4

- Fluid flow and Bernoulli's principle
- Airplanes and curveballs
- Properties of "real fluids"
  - viscosity
  - surface tension

Trivia question: Who is considered the best curve ball pitcher ever?

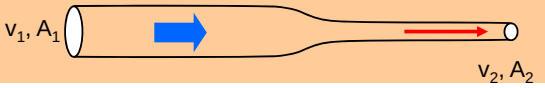
1

Basic principles of fluid dynamics

Volume flow rate = Q_V = v x A (m³/s)

I. Continuity principle: Q_V = constant

$v \times A = \text{constant} \rightarrow v_1A_1 = v_2A_2$



II. Bernoulli's principle: as the speed of a fluid increases, its pressure decreases

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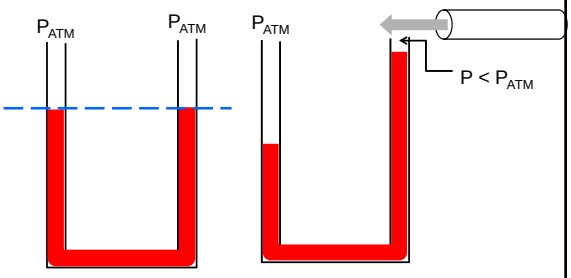

Blowing air over the top of the tube lowers the air pressure on that side allowing the fluid to rise

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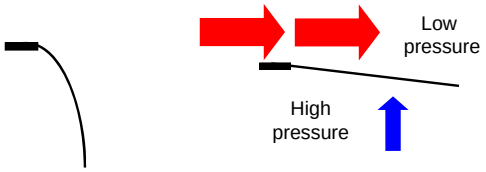
Bernoulli's principle

- fast flow → low pressure
- slow flow → high pressure



No flow

Flow on top

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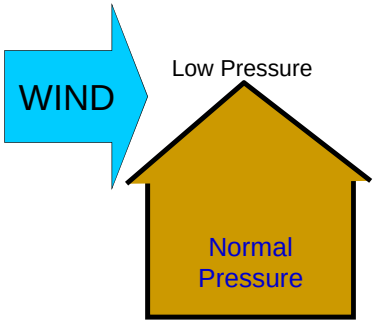
Loosing your roof in a tornado



The wind does not blow the roof off. The wind lowers the pressure above the roof and the normal pressure inside the house blows the roof off.

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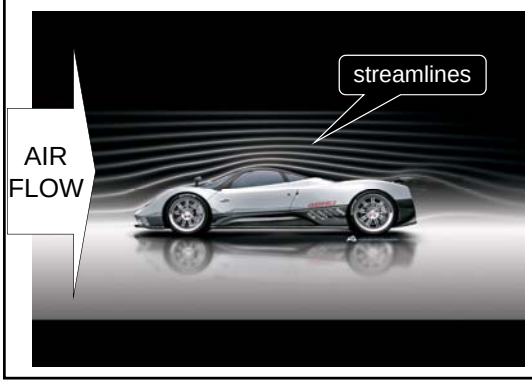
visualization of air flow in a wind tunnel



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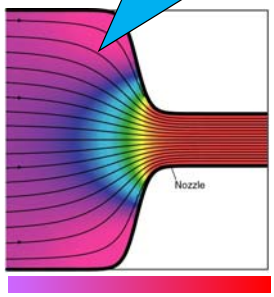
Streamlines and fluid flow



- The black lines are the paths (streamlines) that the fluid takes as it flows.
- Wider spacing indicates low speed flow, closer spacing indicates high speed flow
- Color indicates pressure

High pressure — Low pressure

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Bernoulli's Principle

- Fluid flow velocity = v
- Fluid pressure = P

→ where v is high, P is low
→ where v is low, P is high

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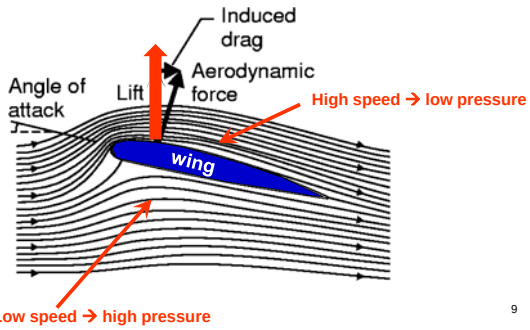
Streamlines around a wing

From the perspective of the jet, the air is moving past it



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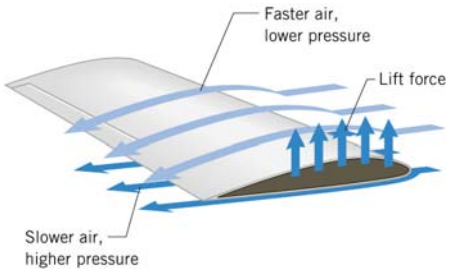
Flow over an airplane wing



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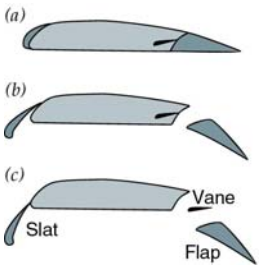
Control surfaces on a plane



- By extending the slats and flaps, the wing area can be increased to generate more lift at low speeds for takeoff and landing

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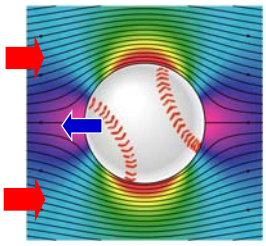
A baseball that is not spinning



- The ball is moving but from the ball's perspective the air moves relative to the ball
- The streamlines are bunched at the top and bottom indicating higher flow speed
- The pressure forces are balanced

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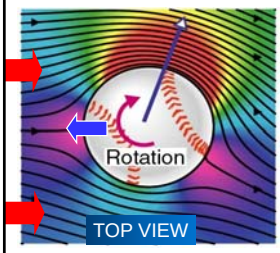
A Spinning baseball



- The clockwise rotation of the ball cause the air to flow faster over the top
- The streamlines are closer together on the top → high speed flow
- The air pressure is then lower on the top than on the bottom (Bernoulli)
- The ball experiences a sidewise force

Dimples on a golf ball allow it to fly farther

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Properties of "real liquids"
1. Viscosity

- so far we have considered only "ideal" liquids → *liquids that can flow without any resistance to the flow*
- "real" liquids (like ketchup) have a property called **viscosity** which is a *tendency for the liquid to resist flowing*

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Viscosity

- for example – pancake syrup flows more slowly than water – we say that pancake syrup is more "viscous" than water.
- Ketchup and molasses are also good examples
- viscosity is sometimes referred to as the *"thickness"* of a liquid
- viscosity is an important property of engine oil – it should maintain its viscosity when **hot,** and not get too viscous when **cold**

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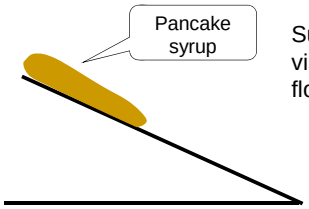
Seeing the effects of viscosity



Substances with higher viscosity take longer to flow down the ramp.

Viscosity is a measure of the resistance that one layer of liquid experiences when flowing over another layer.

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Viscosities of various substances

- water has a viscosity of about 1 unit
- pancake syrup has a viscosity of 2500
- ketchup has a viscosity of 98,000
- Lava- 100,000
- peanut butter has a viscosity of 250,000
- glass is a liquid with a very high viscosity of 10^{17} → it does flow, but very slowly!
- *viscosity depends on temperature* → warm syrup flows faster than cold syrup

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Pitch drop experiment at the University of Queensland in Brisbane, Australia

- Pitch- used as a roofing material to prevent leaks
- Must be heated to be applied
- viscosity ~ 10^{11} x water
- Experiment began in 1927
- 8 drops have since fallen, one every decade or so

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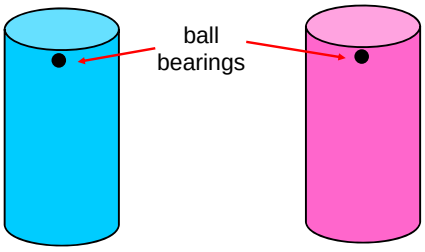
Measuring viscosity



low viscosity
Liquid (e. g. water)

high viscosity
Liquid (e.g. syrup)

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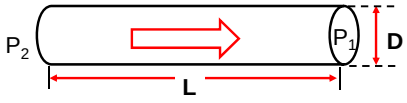
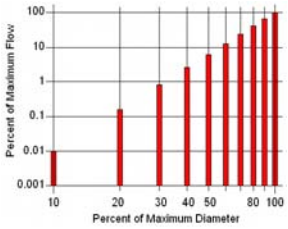
Flow through a pipe



Poiseuille's Law

$$Q_V \propto \frac{(P_2 - P_1)\, D^4}{L\, \eta}$$

D is the diameter
L is the length
$P_2 - P_1$ = pressure difference
η (eta) is the viscosity



A pipe clogged
With calcium
deposits

clogged arteries

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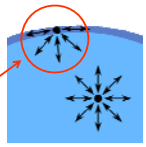
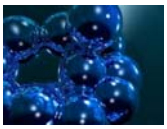
2. Surface tension

An attractive force between molecules at the surface of a liquid.



The surface tension force allows light objects and insects to sit on a water surface, and causes bubbles to merge.



This effect is NOT due to a buoyant force

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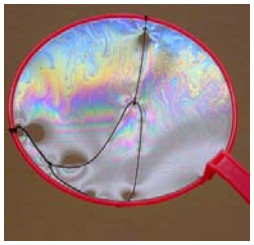
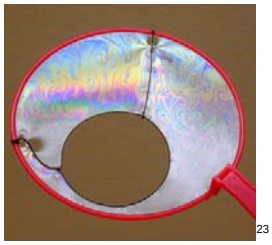
If a segment of the soap film is punctured, surface tension pulls the strings apart





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