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?

Basic principles of fluid dynamics
Volume flow rate \( Q_v = v \times A \) \((m^3/s)\)

I. Continuity principle: \( Q_v = \text{constant} \)
\[ v_1 \times A_1 = v_2 \times A_2 \]

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

Bernoulli’s principle
• fast flow \(\rightarrow\) low pressure
• slow flow \(\rightarrow\) high pressure

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

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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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.

Bernoulli’s Principle

- Fluid flow velocity = v
- Fluid pressure = P

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

Streamlines around a wing

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

Flow over an airplane wing

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.

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.
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 \rightarrow 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

Properties of “real liquids”

1. Viscosity

- so far we have considered only “ideal” liquids \rightarrow 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

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

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.

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 $10^{11}$ \rightarrow it does flow, but very slowly!
- viscosity depends on temperature \rightarrow warm syrup flows faster than cold syrup

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 $\sim 10^{11} \times$ water
- Experiment began in 1927
- 8 drops have since fallen, one every decade or so
Measuring viscosity

Low viscosity liquid (e.g. water)

High viscosity liquid (e.g. syrup)

Flow through a pipe

\[ Q \propto \frac{(P_2 - P_1) \cdot D^4}{L \cdot \eta} \]

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

A pipe clogged with calcium deposits

Clogged arteries

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

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