L 15 Fluids [4]

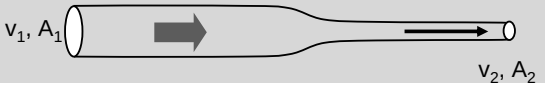
- Fluid flow and Bernoulli's principle
- Airplanes and curveballs
- viscosity
- surface tension

Basic principles of fluid dynamics

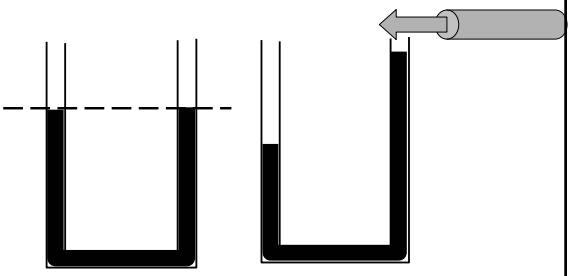
Volume flow rate = Q_V = v x A (m^3/s)

I. Continuity principle: Q_V = constant

$v \times A$ = constant → $v_1A_1 = v_2A_2$



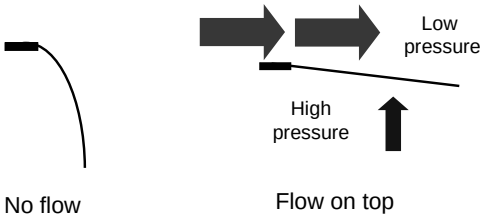
II. Bernoulli's principle: the pressure in a moving fluid is less than the pressure in a static fluid



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

Bernoulli's principle

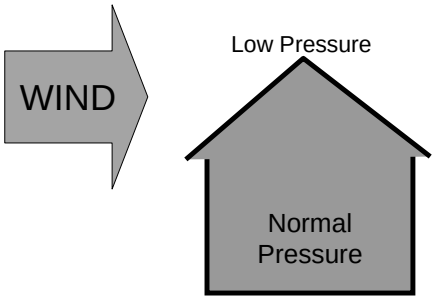
- fast flow → low pressure
- slow flow → high pressure



No flow

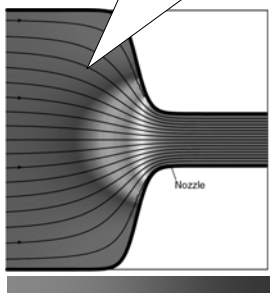
Flow on top

Loosing your roof in a tornado



Wind tunnel visualization of air flow

Streamlines and fluid flow



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

High pressure **Low pressure**

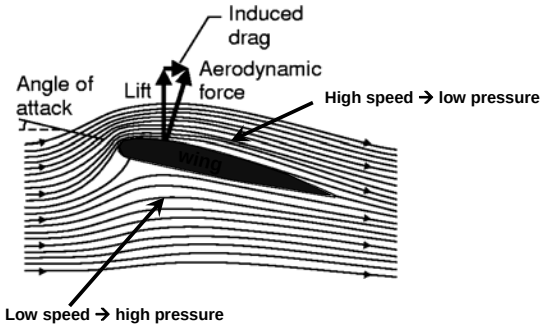
Bernoulli's Principle

- Fluid flow velocity = v
- Fluid pressure = P

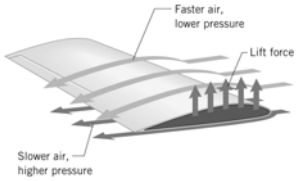
→ where v is high, P is low
→ where v is low, P is high

Streamlines around a wing

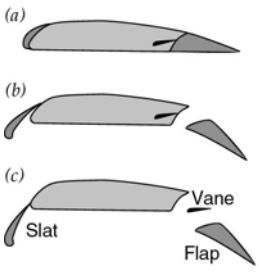
From the perspective of the jet, the air is moving past it



Flow over an airplane wing

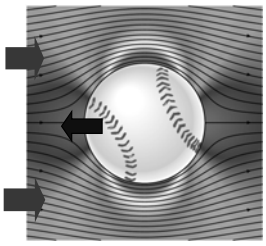


Control surfaces on a plane



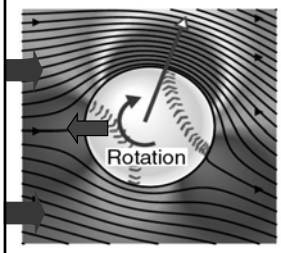
- By extending the slats, the wing area can be increased to generate more lift at low speeds for takeoff and landing

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 → high speed flow
- By Bernoulli's principle, the air pressure is then lower on the top than on the bottom
- The ball experiences a sidewise force

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*

- 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 the most important property of motor oil

Engine oil

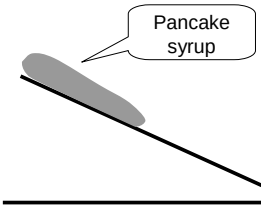
- SAE – Society of American Engineers
- the viscosity of oil tends to decrease as it heats up (oil breakdown)
- what does 10W-30 mean?

viscosity index- cold engine

viscosity index- hot engine

A higher viscosity index indicates the viscosity changes less with temperature than a lower viscosity index.

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.

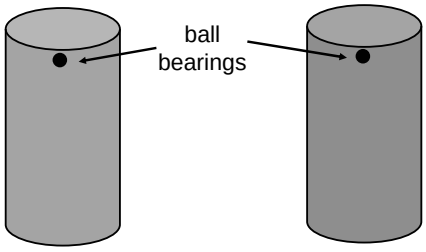
Viscosities of various substances

- 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^{17} → it does flow, but very slowly!
- *viscosity depends on temperature* → 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 ~ 10^{11} water
- Experiment began in 1927
- 8 drops have since fallen, one every decade or so

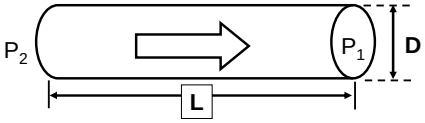
Measuring viscosity



low viscosity
Liquid (e. g. water)

high viscosity
Liquid (e.g. syrup)

Flow through a pipe



Viscosity slows the flow of a fluid through a pipe

Poiseuille's Law

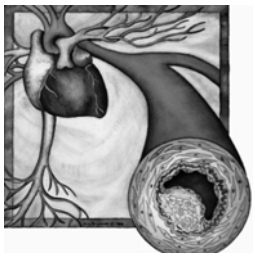
$$Q_V = k\frac{(P_2 - P_1)\,D^4}{L\,\eta}$$

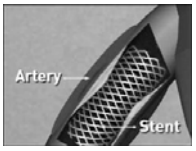
η(eta) is the viscosity of the fluid, *k* is a constant

- A 10 % reduction in diameter reduces the flow by 34 %
- If D → D/2, the flow is reduced by 94 %

A pipe clogged With calcium deposits

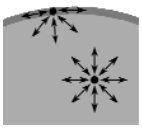
clogged arteries



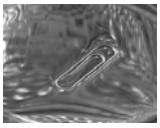


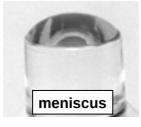
Surface tension

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



The surface tension force allows light objects to be suspended on a water surface





This effect is NOT due to the buoyant force

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