14.1: Newtonian Fluids

- Fluids described through continuum mechanics.
  - Stress: Force applied to an object. Stress is force applied over a surface area, a. Force has normal (z) and parallel components (x).
  - The stress can be decomposed it into the normal component perpendicular to the surface $\vec{f}_z/a$, and the sheer stress parallel to the surface $\vec{f}_x/a$.
  - Strain: The deformation (change in dimension) of object as a result of the stress.
- Solids
  - A solid is considered Newtonian if its behavior follows a linear relationship between elastic stress and strain, i.e. Hooke's Law.
  - Solids are stiff and will return to their original configuration when stressed, but can't deform far (without rupture).
- Fluids
  - Fluids cannot support a strain and remain at equilibrium. Conservation of momentum dictates that application of a force will induce a flow.
  - Fluids resist flow (viscous flow).
  - Newtonian fluids follow a linear relation between shear stress and the strain rate.

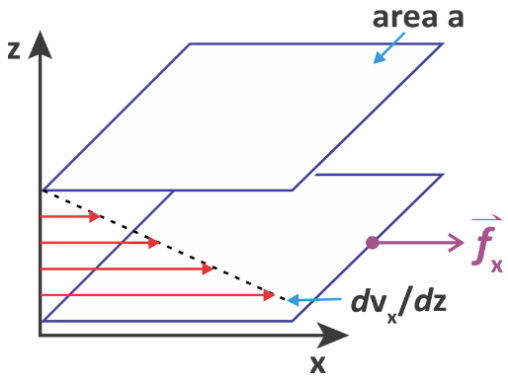
Viscosity

Viscosity measures the resistance to shear forces. A fluid is placed between two plates of area a separated along z, and one plate is moved relative to the other by applying a shear force along x. At contact, the velocity of the fluid at the interface with either plate is equal to the velocity of the plate as a result of intermolecular interactions: $\vec{v}_x(z=0)=0$. This is known as the no-slip boundary condition. The movement of one plate with respect to the other sets up a velocity gradient along z. This velocity gradient is equal to the strain rate.

The relationship between the shear velocity gradient and the force is

$$\vec{f}_x = a\eta\frac{d\vec{v}_x}{dz}$$

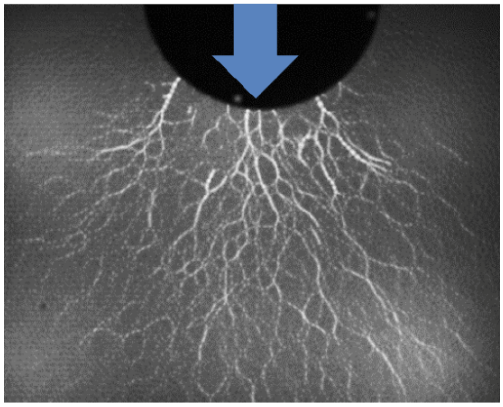
where η, the dynamic viscosity (kg m^{-1} s^{-1}), is the proportionality factor. For water at 25°C, the dynamic viscosity is η = 8.9×10^{-3} Pa s.



Stresses in a Dense Particle Fluid

A normal stress is a pressure (force per unit area), and these forces are transmitted through a fluid as a result of the conservation of momentum in an incompressible medium. This force transduction also means that a stress applied in one direction can induce a strain in another, i.e. a stress tensor is needed to describe the proportionality between the stress and strain vectors.

In an anisotropic particulate system, force transmission from one region of the fluid to another results from "force chains" involving steaming motion of particles that repel each other. These force chains are not simply unidirectional, but also branch into networks that bypass unaffected regions of the system.



	Adapted from National Science Foundation, “Granular Materials”, June 15, 2012. Copyright 2012 National Science Foundation. https://www.youtube.com/watch?v=R7g6wdmYB78	