Lecture 21, Oct 21, 2022

What is a Fluid?

- With a solid, when a small shear force is applied, we get a small angular deformation, but it stops at equilibrium even when the force is applied continuously
- However the same applied to a fluid will cause the fluid to deform continuously as long as the force is applied
- No slip condition: fluid in direct contact with a solid boundary sticks to it, i.e. it has zero velocity relative to the solid boundary

Definition

A fluid is a substance that deforms *continuously* under the application of a tangential (shear) force, no matter how small the force

- Note, this definition does not address the rate of deformation
- Thus a fluid at rest is always at a state of zero shear force

Studying Fluids

- Two approaches:
  1. Statistical approach: account for the molecular nature of the fluid
     - Macroscopic behaviour of the fluid is determined through statistics and kinetic theory
     - However not practical in most engineering applications
  2. Continuum approach: ignore individual molecules and treat the fluid as a continuous matter
     - More practical for typical engineering applications
     - Will be used in this course
- The continuum approach requires that the macroscopic length scale (size of the system) is much larger than the microscopic length scale (gap between molecules)
  - This is captured in the Knudsen number Kn which is the ratio of the microscopic to the macroscopic length scales
- The continuum approach fails when:
  - Flow through tiny passages, e.g. blood in a vessel
  - Granular flows, e.g. sand
  - Flows with shockwaves, e.g. wake of a supersonic bullet
  - When there is a sudden jump in pressure/temperature, e.g. when a spacecraft enters the atmosphere
- With the continuum approach, we can apply limit concepts from calculus (e.g. work with differentials and infinitesimals) and talk about "points" in the fluid

Important

The continuum approach is only valid when the macroscopic length scale (size of the system) is much larger than the microscopic length scale (gap between molecules) of the fluid