09 - 16 Jan Office Hours Mon & Fri 2-3pm

1 Fluid Mechanics

Motivation: applications in astrophysics, atmospheric physics, geophysics, oceanography, chemical and mechanical engineering, etc.

Note. Macroscopic properties are used in describing fluids. How can we make a leap from describing points to describing fields?

Example 1.1
UV light frow white dwarves causes gases to flow – fluid mechanics allows us to model their movement.

Definition 1.2. Fluids – liquids or gases (with pressure and density as main descriptive parameters)

- flow when acted upon by external force
- liquid
  - almost incompressible
  - packed – both order and movement are present
- gas
  - compressible
  - disordered – random motion dominates

Note. More interesting definitions exist – cf. nonlinear fluid dynamics

Example 1.3 (Liquid Behaviour in Zero Gravity)
Scott Kelly has shown that you can play ping pong in space.

For static fluids, the following formulas apply:

density $\rho = \frac{\text{mass}}{\text{volume}}$ unit: $\frac{kg}{m^3}$

pressure $P = \frac{\text{force}}{\text{area}}$ unit: $Pa = \frac{N}{m^2}$

- pressure acts normally

Example 1.4
approximately every 16 km up the atmospheric pressure goes down by an order of magnitude.

Question. How do we check that P varies continuously with height?

Answer. Determine a unit volume small enough for P to be constant and large enough to behave as a fluid. In this way,

$$\rho = \lim_{\Delta V \to 0} \frac{\Delta m}{\Delta V}$$

Consider pressure of a fluid at rest.

Note that since the fluid is at rest, all force components acting on a parallellopiped cancel each other out.

Thus,

$$\rho_l A' = \rho_r A' \tag{1}$$
$$\rho_f A' = \rho_n A' \tag{2}$$
$$\rho_t A + mg = \rho_b A \tag{3}$$
$$\Rightarrow P_b = P_t + \frac{mg}{A} \tag{4}$$
$$m = \rho_f A d \Rightarrow P(d) = P(t) + \rho_f g d \tag{5}$$

1.1 Measurement Methods

- gauge pressure = absolute pressure - atmospheric pressure
- used for tires, sports equipment