Fluid Mechanics

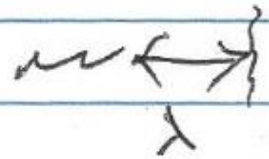
Fluid Mechanics – a Topic in classical physics

A fluid is a substance (gas or liquid) where intermolecular forces are medium or weak. and there is a significant random thermal movement of molecules and disorder arrangement.

The continuum hypothesis

A fluid is modelled as a continuum, i.e. mater that is exhibiting no structure however small it is divided.

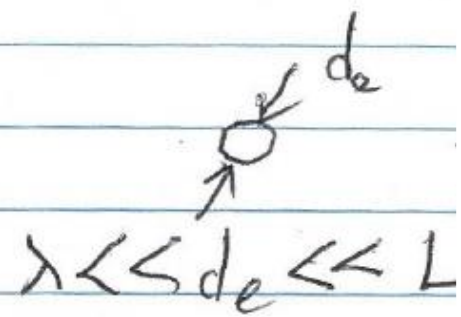
Mean free path of molecules is the distance λ for molecules' collision



$\lambda \sim 10^{-7}$ (m) for air at STP condition.
$\lambda \gtrsim 1$ (m) at the edge of atmosphere.
$\lambda \sim 10^{-10}$ (m) in water liquid

Let L be a characteristic length of interest.
For continuum behavior, $\lambda \ll L$
Knudsen number $Kn = \frac{\lambda}{L} \ll 1$

A fluid element is a region in the flow of the fluid that is infinitesimally small but larger than λ and much smaller than L. Each element contains many molecules.



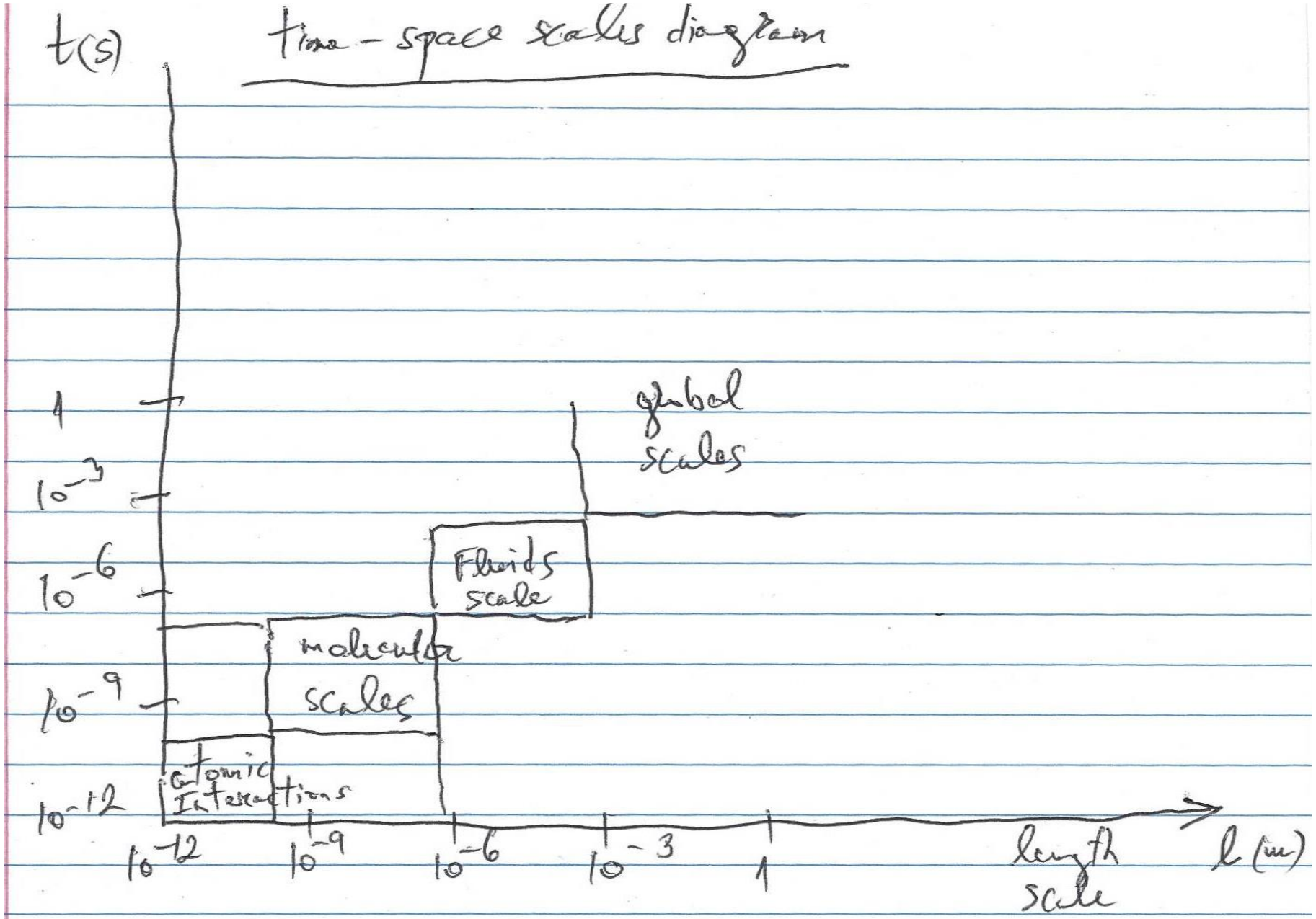
We also have a characteristic time of collision for thermal equilibrium, τ

$\tau < 10^{-8}$ (s) in air at STP conditions

For continuum behavior, $\tau \ll \mathcal{T}$

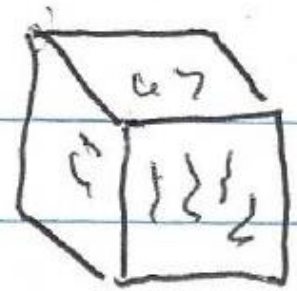
where $\mathcal{T}$ is the characteristic time of interest.

time - space scales diagram



Fluid properties

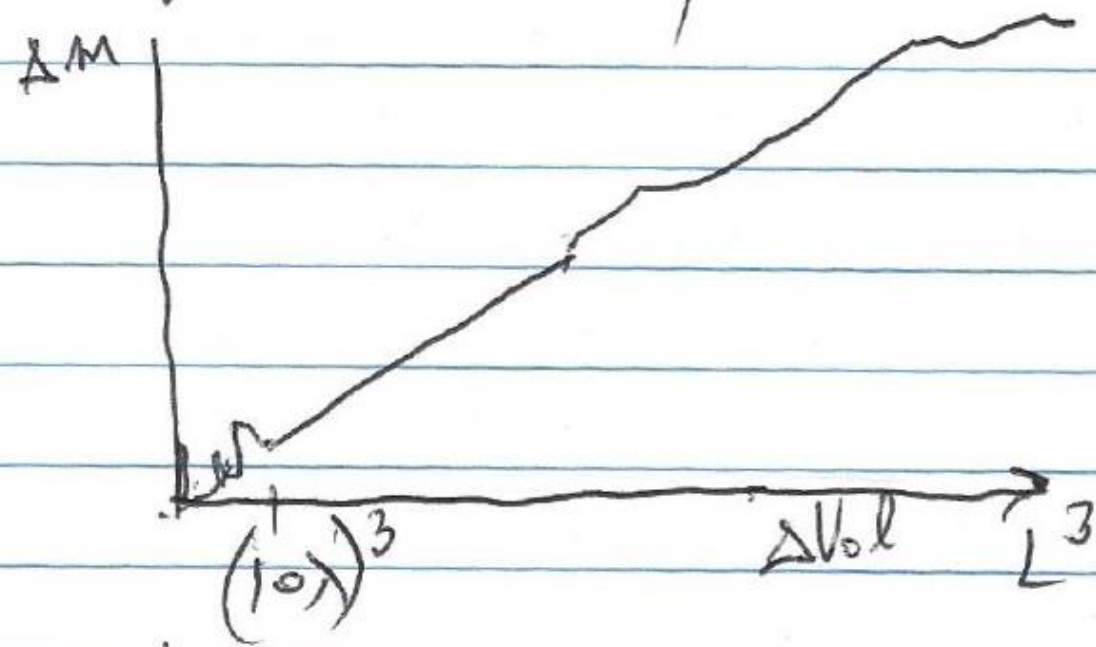
density



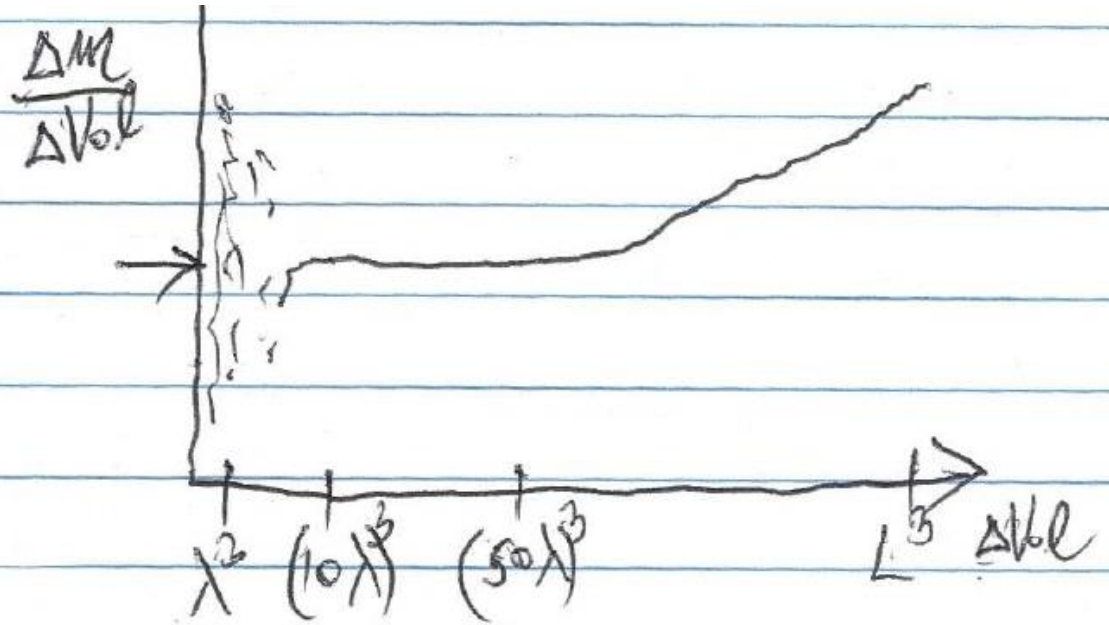
ΔVol

$\Delta m = \sum m_{molec\ insite\ \Delta Vol}$

as the ΔVol goes below λ^3, Δm loses it identity



Density of a fluid element



density of a fluid element: $\rho = \lim_{\Delta Vol \to (\Delta Vol)_{min}} \frac{\Delta m}{\Delta Vol}$

$(\Delta Vol)_{min} \sim (10\lambda)^3$

specific volume: $v = \frac{1}{\rho}$