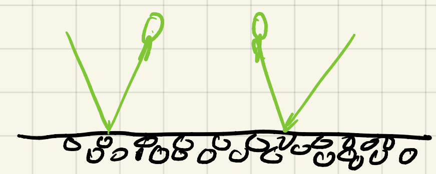
lecture 01

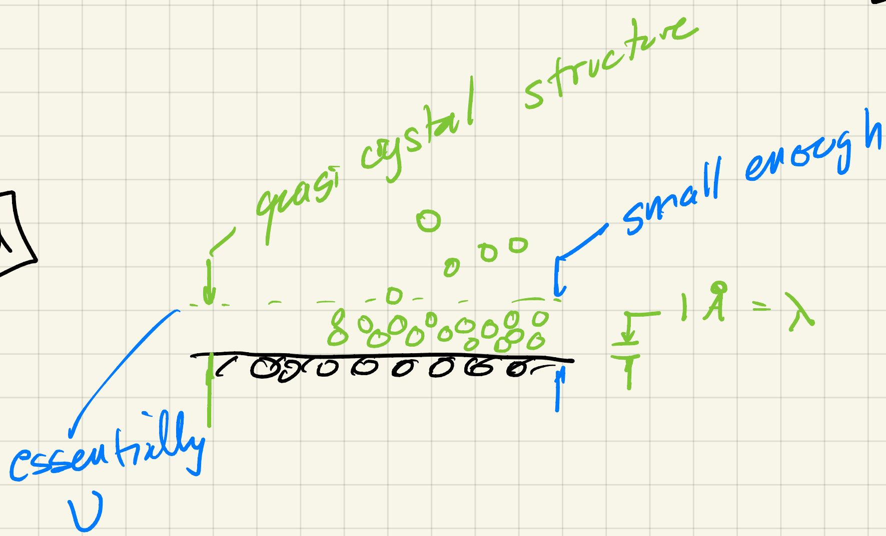
Q: what happens

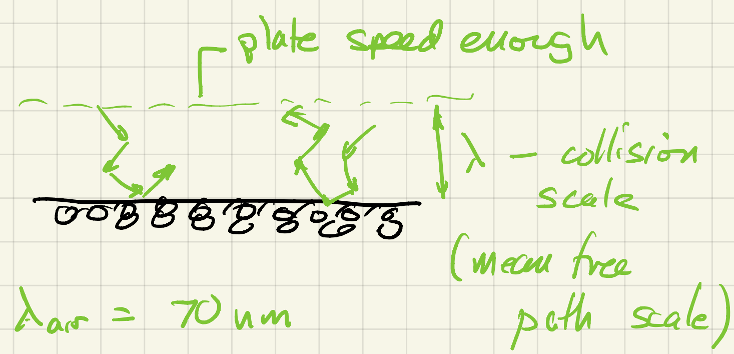
- no slip $u(y=0) = U$

gas



Liquid



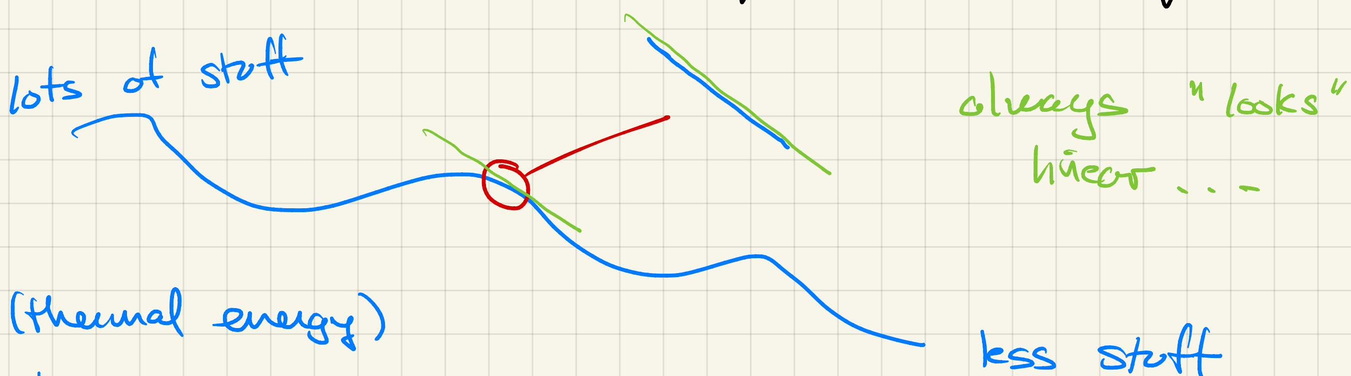


summary: always <u>some</u> slip, almost always negligible if $L \gg \lambda$

- diffusion of momentum

  - meaning? diffusion = gradient driven transport

  - molecular process ⟶ v. small scale
    ⟶ linear dependence on gradient



<u>stuff?</u> - heat (thermal energy)
- momentum
- concentration

$$\frac{(\text{stuff})}{\text{area time}} \propto \bigcirc \frac{\partial}{\partial x}\left[\frac{(\text{stuff})}{\text{volume}}\right]$$

$$\frac{1}{L^2 T} \qquad \frac{L^2}{T} \qquad \frac{1}{L} \qquad \frac{1}{L^3}$$

← diffusivity units

→ momentum

$$\frac{\text{momentum}}{\text{volume}} = \frac{\text{mass} \times \text{vel}}{\text{volume}} = \rho \underset{\sim}{u}$$

also mass flux

$\rho \underline{u} \rightarrow \frac{\text{mass}}{\text{area time}}$

$\rightarrow \frac{\text{mom}}{\text{volume}}$

→ momentum diffusivity

kinematic viscosity $\quad \nu \equiv \mu / \rho$

no ρ

no "mass"

dynamic viscosity

NS Equations

$$\rho \frac{\partial \underline{u}}{\partial t} + \rho \underline{u} \cdot \nabla \underline{u} = -\nabla p + \nabla \cdot \left[\mu \left(\nabla \underline{u} + \nabla \underline{u}^T \right) + \lambda (\nabla \cdot \underline{u}) \right]$$

2nd coef. of viscosity

μ_{bulk} – related to λ

$\rho = \text{const}$

$\mu = \text{const}$

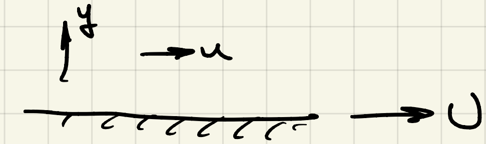
$\nabla \cdot \underline{u} = 0$

1D

$v = w = 0$

$\frac{\partial}{\partial x}, \frac{\partial}{\partial z} = 0$

$$\frac{\partial u}{\partial t} = \nu \frac{\partial^2 u}{\partial y^2}$$



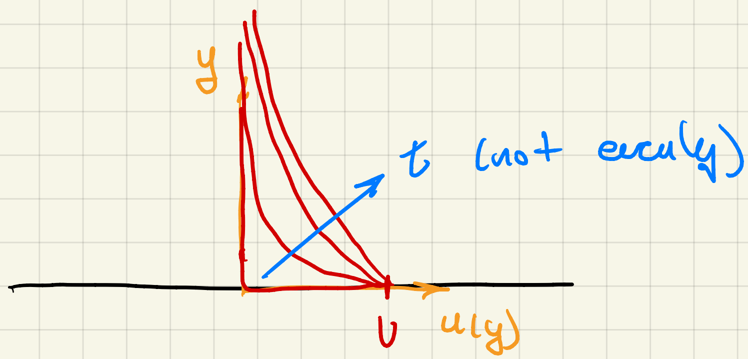
$$\tau_{xy} = \mu \frac{\partial u}{\partial y}$$

$\hookrightarrow \nabla \times \underline{u} = \underset{\sim}{\omega}$

also diffuses $\quad \frac{\partial \omega}{\partial t} = \nu \frac{\partial^2 \omega}{\partial y}$

gradient of momentum

$$\underbrace{\frac{\text{Force}}{\text{Area}} \rightarrow \text{stress}}_{\text{changes momentum}}$$



- How thick after 1s? $\qquad t = 1\,s$

$\delta_{99} \rightarrow \quad u = 0.99\,U$

$\delta_{99} = f(\nu, t) \rightarrow$ nondimensionalize

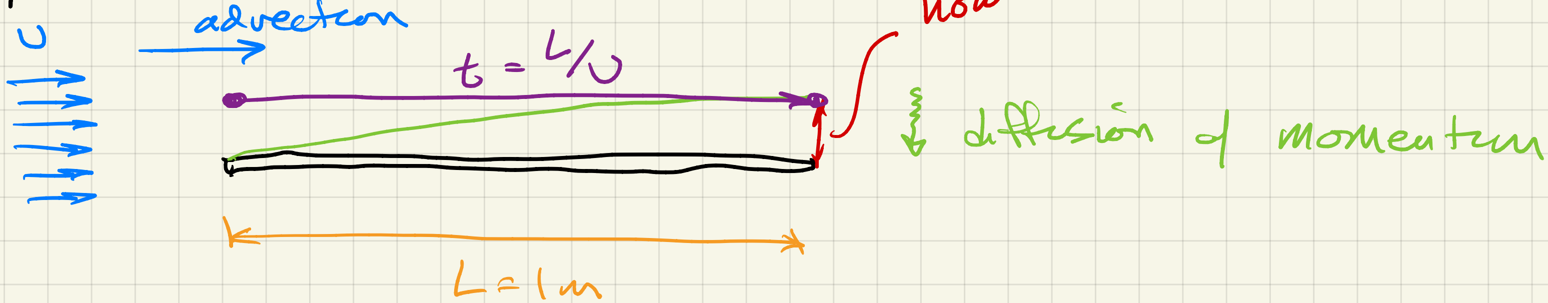
$$\frac{\delta_{99}}{(\nu t)^{1/2}} = \text{const}$$

assume const $\approx$ 1

$$\nu_{air} = 10^{-5}\ m^2/s \qquad (\nu t)^{1/2} = 10^{-2.5}\ m$$

mm $\to$ cm

- finite plate



$$\delta_{99} \approx (\nu t)^{1/2} = \left(\frac{\nu L}{U}\right)^{1/2}$$

$$\frac{L}{\delta_{99}} = \underbrace{\left(\frac{UL}{\nu}\right)}_{\to \text{ Re\#}}^{1/2}$$

δ also small

$\sim$ mm to cm