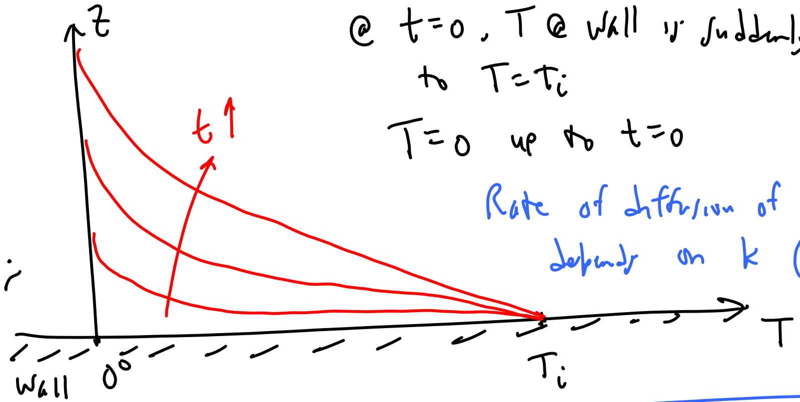
Today, we will:

- Continue our discussion of **gradient diffusion**
- Discuss the **Reynolds analogy**
- Discuss **evaporation of a pure liquid in stagnant air – Section 4.5**
- Do some example problems

Example: mass – momentum – energy analogy for a step change

Energy:

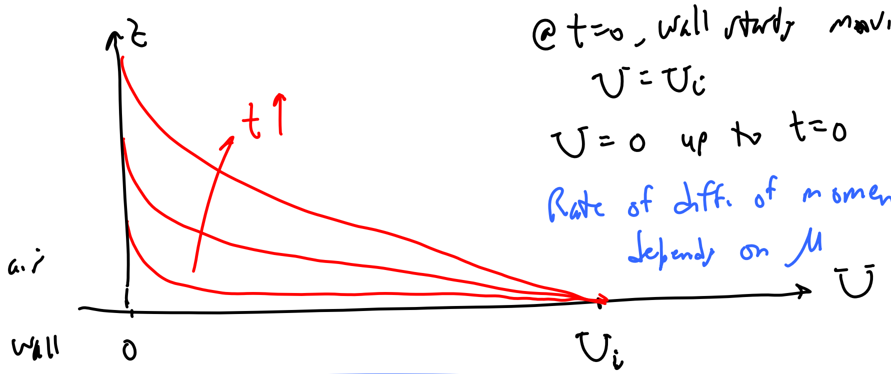


@ $t=0$, T @ wall is suddenly increased to $T=T_i$

$T=0$ up to $t=0$

Rate of diffusion of heat depends on k (thermal conductivity)

Momentum

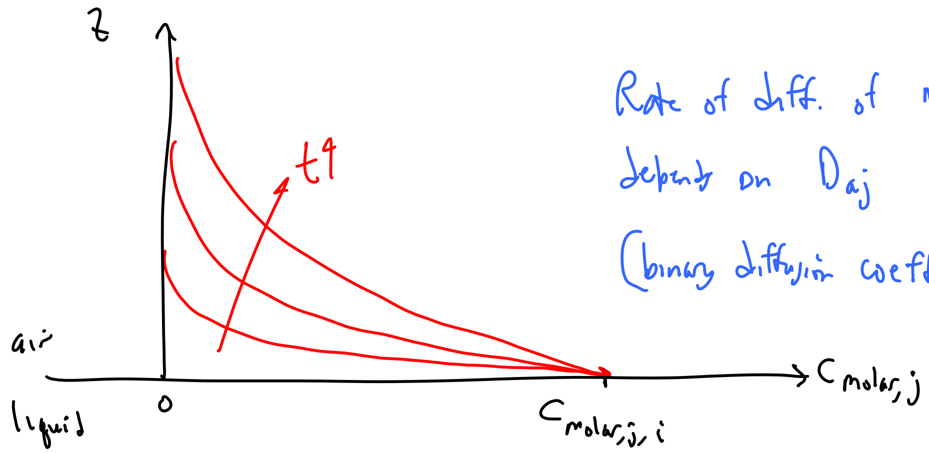


@ $t=0$, wall starts moving @ $U=U_i$

$U=0$ up to $t=0$

Rate of diff. of momen. depends on μ

Mass



Rate of diff. of mass depends on D_{aj} (binary diffusion coeff.)

Imagine a thin membrane at the interface that is suddenly removed @ $t=0$

The behavior of mass, momen, & energy diffusion is very similar, but with different rates, because of different diffusion coefficients.

Introduce some nondimensional ratios of these diffusion coefficients

- Momen. & mass (μ & D_{aj})

D_{aj} has units of m^2/s

μ has units of $kg/m \cdot s$ → introduce ν = kinematic viscosity

ν .. .. m^2/s $\boxed{\nu \equiv \frac{\mu}{\rho}}$

$$\boxed{S_c = \text{Schmidt \#} \equiv \frac{\nu}{D_{aj}}}$$ = ratio of momen. diffusion to mass diffusion ☆

- Momen. & energy (μ & k) — again use ν

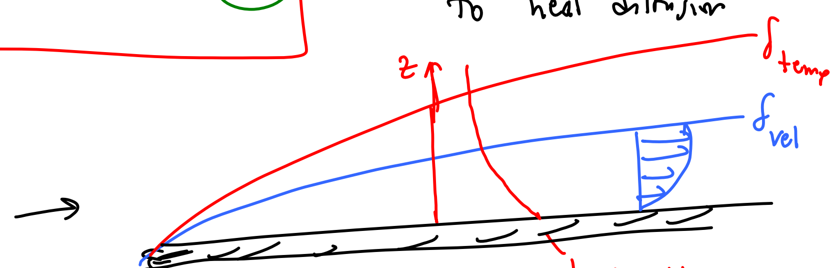
define $\boxed{K \equiv \frac{k}{\rho C_p}}$ = thermal diffusivity units of m^2/s

(kappa)

$$\boxed{P_r = \text{Prandtl \#} \equiv \frac{\nu}{K}}$$ = ratio of mom. diff. to heat diffusion

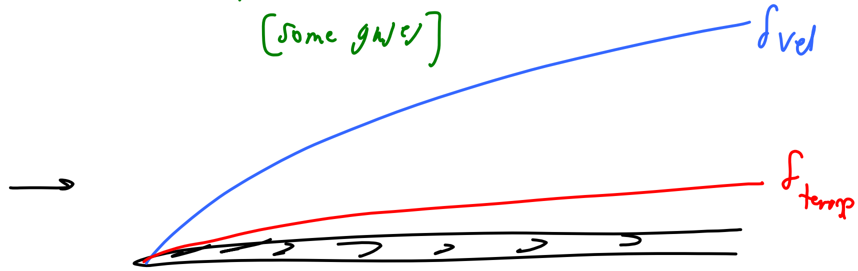
e.g. Boundary layers

(Laminar flow)



$P_r < 1$

[some gases]



$P_r \gg 1$ [eg water]

In air, ν & K are close to each other → ∴ $P_r \simeq 1$

[$P_r \simeq 0.7$]

· Energy & mass

$$\boxed{Le = \text{Lewis } \# = \frac{K}{D_{aj}}}$$

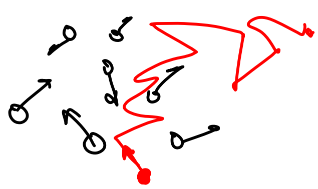
$\# =$ ratio of energy diffusion to mass (or species) diffusion

$$\boxed{Le = \frac{S_c}{P_r}}$$

✪ REYNOLDS ANALOGY

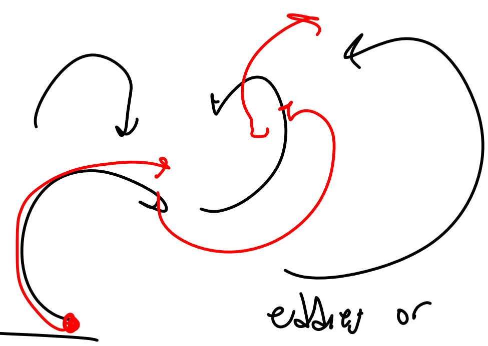
For turbulent flow, heat, mass, & momen diffusion are still related, but diffusion is a macroscopic rather than microscopic phenomenon

Laminar diffusion



gas molecules

Turbulent Diffusion



eddies or vortices

$$\boxed{\text{Diffusion coefficients for turbulent flow} \gg \text{" " " laminar "}}$$ ✪

✪ Reynolds Analogy

But the analogy between the 3 still holds

Usefulness

- Can easily measure heat transfer characteristics (lots of data)
  We have correlations (Nusselt # vs Reynolds #, etc.)
- We can apply these heat xfer correlations to species transfer, which are harder experiments to conduct

[This is what we do in Chap. 4]

☆ EXAM 1 MATERIAL ENDS HERE

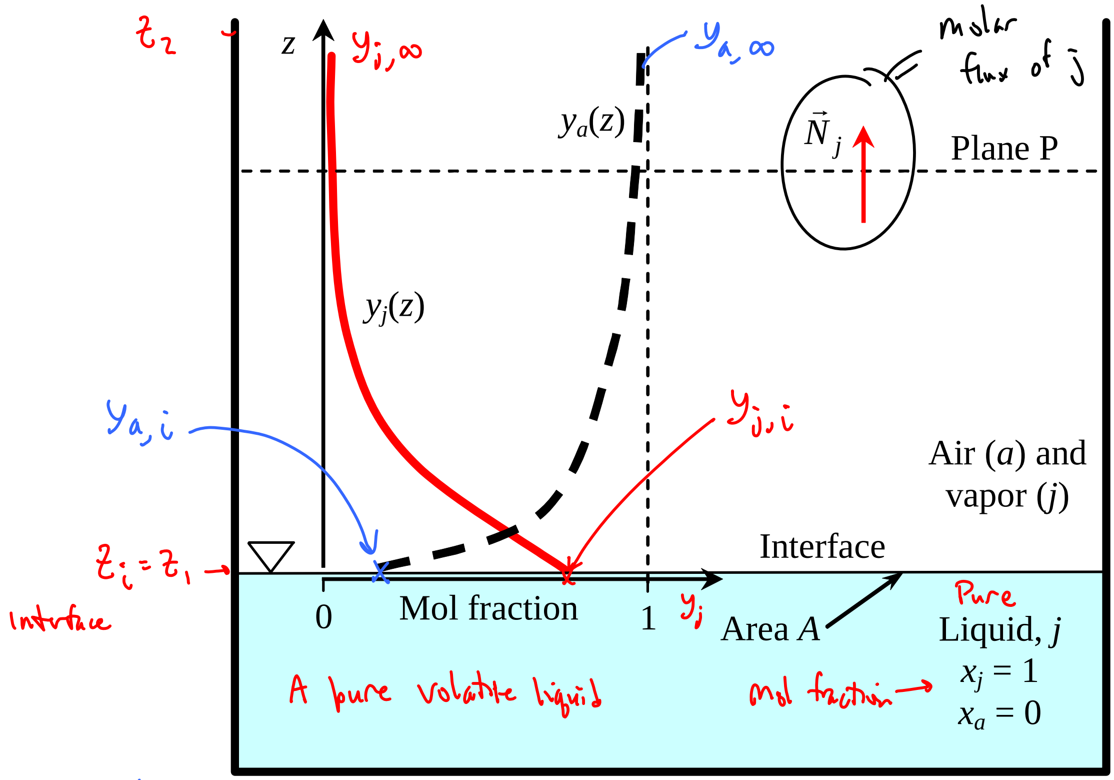
[up to Sec. 4.5]

EXAM 1

EXAM 2

Sec. 4.5 Evaporation of a liquid from a container;

Section 4.5.3 – Evaporation of a liquid from a container, open to nearly stagnant air on top:



$\sum y_j = 1 \rightarrow \therefore \boxed{y_a + y_j = 1}$

For a pure liquid (species j), $\underline{P_{j,i}} = \underline{P_{v,j}}$ at the interface

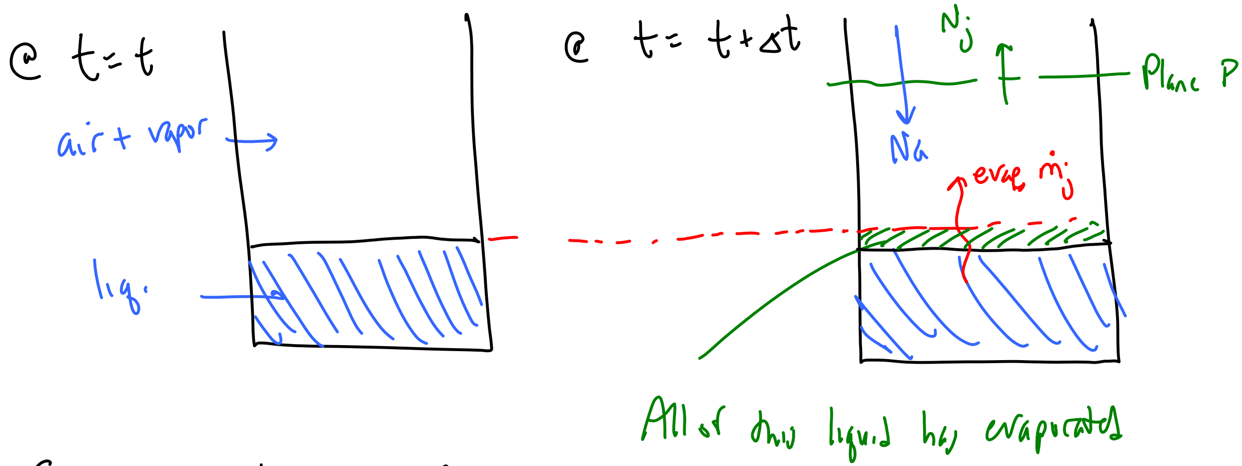
recall, $y_j = \frac{P_j}{P_{atm}} \rightarrow \therefore \boxed{y_{j,i} = \frac{P_{v,j}}{P_{atm}}}$

N_j = molar flux = # mols of species j crossing a fixed plane parallel to the interface per unit area per unit time

Units of N_j are $\frac{kmol}{m^2 \cdot s}$

N_j is similar to J_j except J_j is a relative molar flux

N_j is an absolute molar flux [fixed plane]



From the air's point of view,

air must move down to replace the displaced liquid

$\therefore N_a$ = molar flux of air & is in opposite direction as N_j

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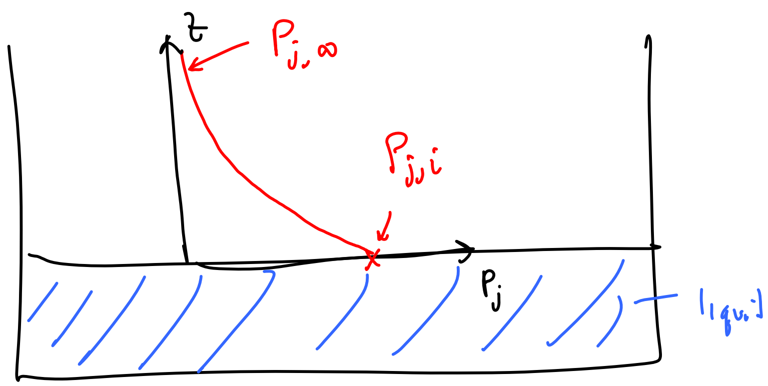
We can also plot in terms of P_j instead of y_j

$$y_j = \frac{P_j}{P} \text{ or } \frac{P_j}{P_{atm}}$$



The larger $D_{a,j}$ the faster the evaporation takes place

[See App A-9 for D_{aj}]

(Also some empirical eqs for D_{aj} in Ch.4)

Equation for $\dot{m}_{evap,j}$

- See book for empirical eqs for N_j

  also for coefficients, sometimes using heat transfer data.

→ Bottom line: $\boxed{\text{eq's for } \underline{\dot{m}_{j,evap}}}$