Today, we will:

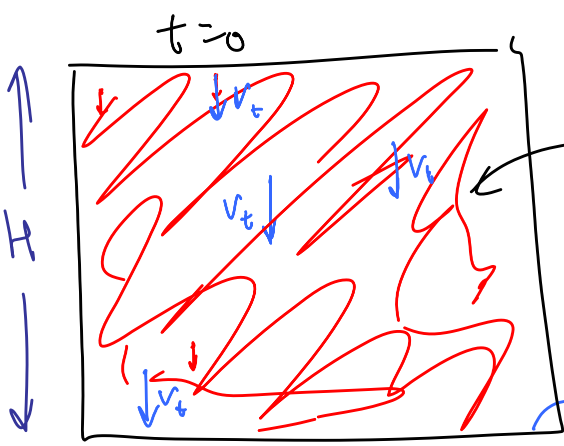
- Continue to discuss applications of gravitational settling (in rooms and in ducts)
- Discuss difference between laminar settling and well-mixed settling

Review of equations for terminal settling velocity:

$V_t = \sqrt{\frac{4}{3}\frac{\rho_p - \rho}{\rho} g D_p \frac{C}{C_D}}$, $C_D = \frac{24}{\text{Re}}$ for Re < 0.1, $C_D = \frac{24}{\text{Re}}(1 + 0.0916\,\text{Re})$ for 0.1 < Re < 5,

$\text{Re} = \frac{\rho V_t D_p}{\mu}$. If Stokes flow (Re < 0.1), $V_t = \frac{\rho_p - \rho}{18} D_p^{\,2} g \frac{C}{\mu}$.

Gravimetric settling in a room



* For simplicity, consider one D_p at a time (pretend we have a monodisperse distribution)

@ t = 0, assume uniform distribution of particles

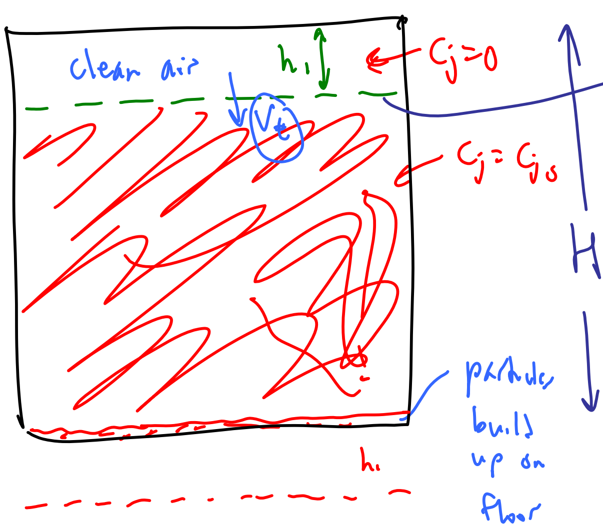
c_{j_0} = initial mass conc. for particles of diameter D_p

Assume particles that hit a wall stick to the wall (or floor) → They are removed

Laminar Settling Model → no mixing, still air

@ $t_1 = \frac{h_1}{V_t}$

$(h_1 = V_t \cdot t_1)$

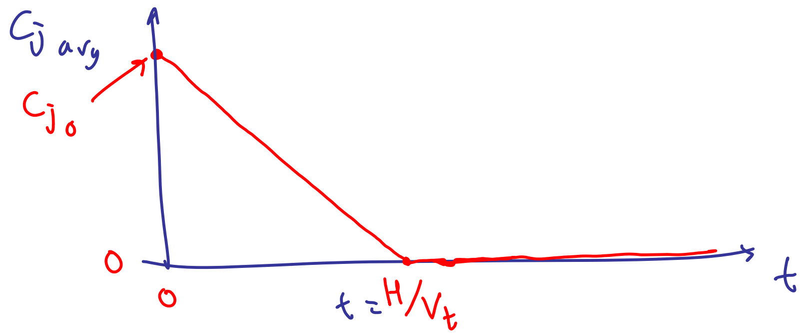


a kind of "piston" pushing particles down at speed V_t

particles build up on floor

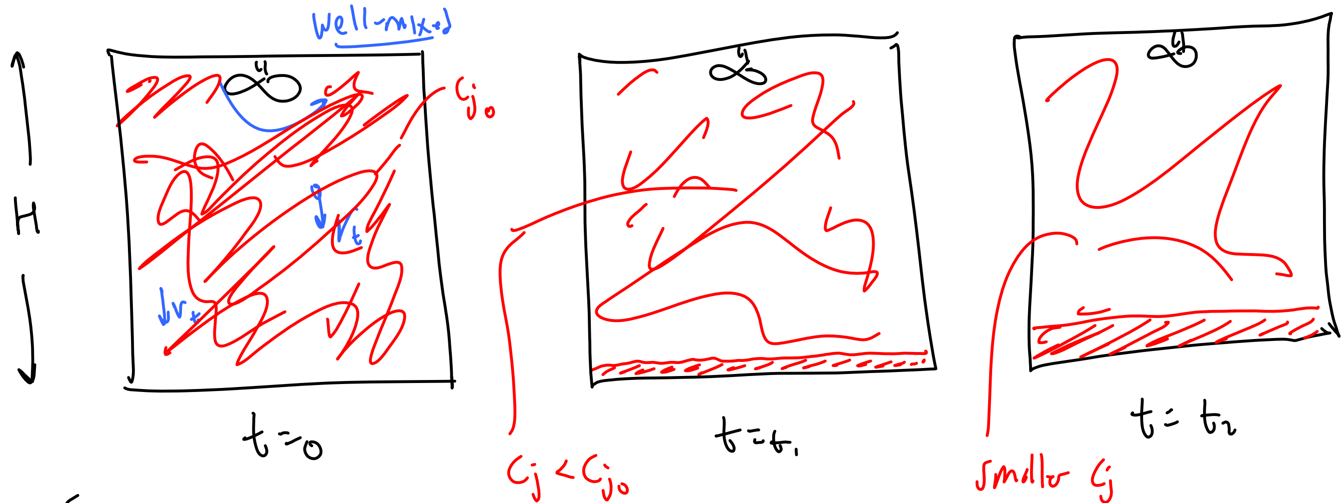
When $t = H/V_t$ the whole room is clean

$C_{j\,avg}$ = average C_j in the room



Well-mixed (turbulent) settling model

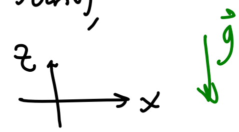
$C_j = C_j(t)$ only – not a fnc of space

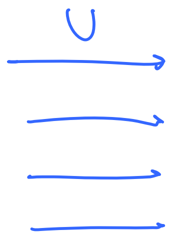


real life → somewhere in between laminar & well mixed

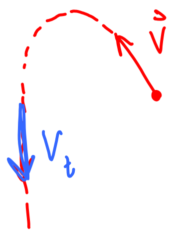
Settling in moving air

instead of $\vec{U} = 0$ (quiescent), let $\vec{U} = U\vec{i}$





Quiescent air



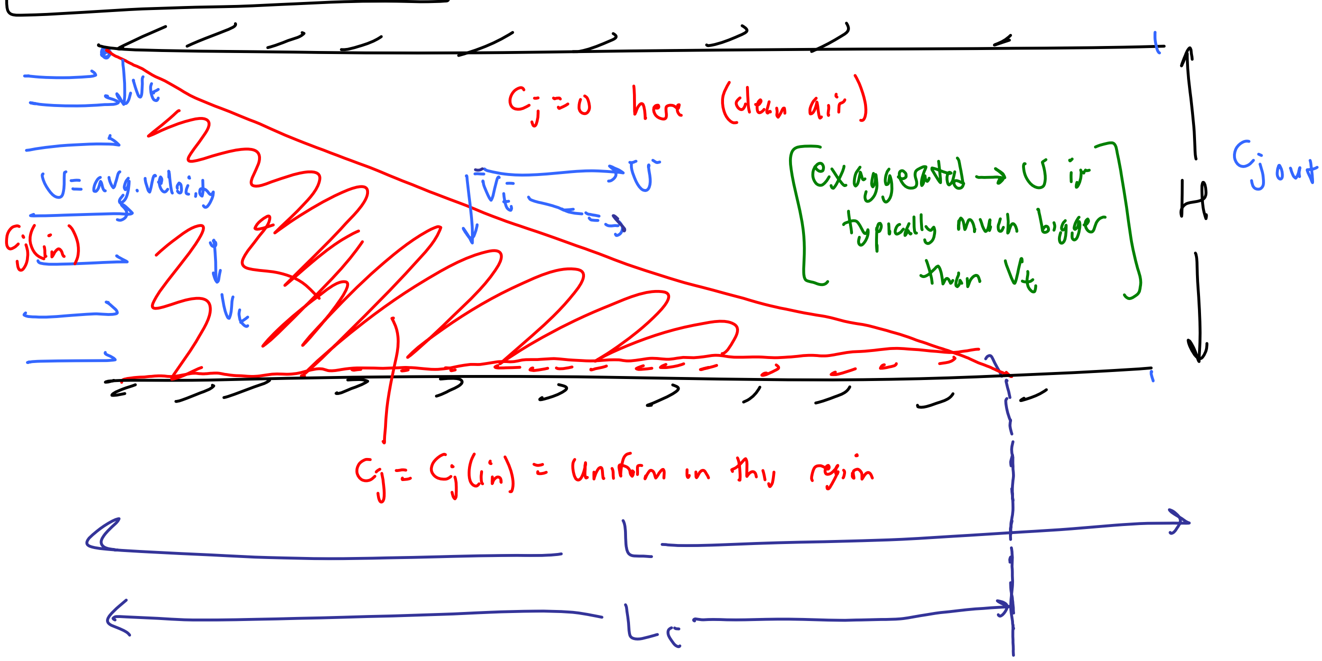
Steady speed air

Gravimetric settling in ducts

Again – assume monodisperse particles (one D_p at a time)

- Both models, laminar & well mixed
- particle that hit floor stay there

LAMINAR SETTLING



L_c = critical length → if $L > L_c$, C_j out $= 0$

if $L < L_c$, C_j out $\neq 0$

at $x = Ut$, $t = x/U$ → in z-direction, particle falls @ V_t

$t = \frac{H}{V_t}$ = time for all particles to settle

Meanwhile $x = Ut$

@ $X = L_c$ this is when $t = \frac{H}{V_t}$ ⇒ $L_c = \frac{HU}{V_t}$ ☆

$t = \frac{L_c}{U} = \frac{H}{V_t}$

required cleaning length to remove all particles

L_c will change with D_p ☆

Removal efficiency will also change with D_p

Example: Removal Efficiency due to Laminar Gravimetric Settling in a Duct

Given: Dusty air enters a horizontal duct of length L = 14.4 m and height H = 6.0 cm at average speed U = 0.20 m/s. Aerosol particles of a certain diameter D_p under consideration have a terminal settling speed of V_t = 0.00025 m/s.

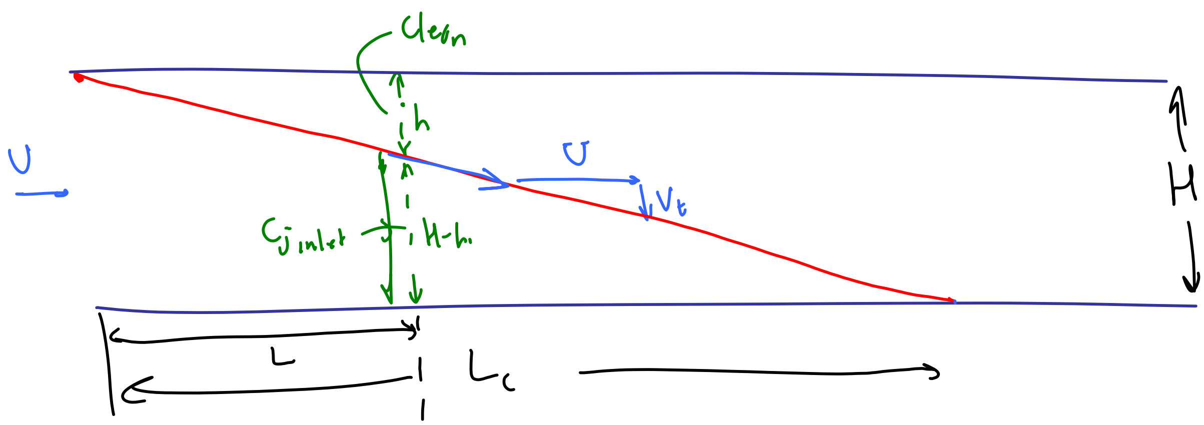
To do: Calculate the removal efficiency E for these particles. Assume laminar settling, and assume that all particles that hit the floor of the duct remain there (they stick to the floor). Give your answer as a percentage to two significant digits.

Solution:

$$L_c = \frac{HU}{V_t} = \frac{(0.06\ \text{m})(0.20\ \text{m/s})}{0.00025\ \text{m/s}} = 48\ \text{m}$$

Here $L < L_c$

$\therefore$ E is between 0 & 100%



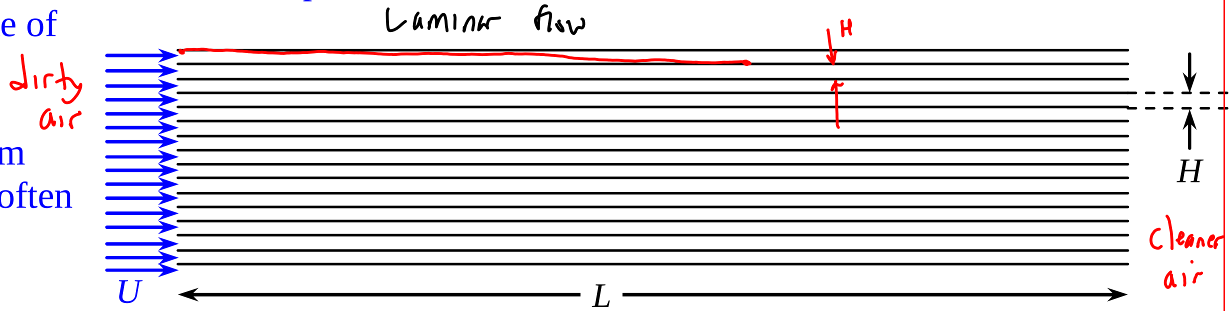
E is linear from $x=0$ to $x=L_c$

$\downarrow$ $E=0$ $\quad$ $\downarrow$ $E=100\%$

$$\frac{L}{L_c} = \frac{E}{100\%} \rightarrow E = \frac{L}{L_c} \times 100\% = \frac{14.4}{48} \times 100\% = \boxed{30\%}$$

Practical Application – Horizontal Elutriator

A **horizontal elutriator** is a simple device that is sometimes used at the inlet to an APCS to remove some of the larger diameter particles from the air. It is often used in coal mines, for example. It consists of parallel horizontal plates, as sketched. Dirty air enters from the left at low air speed. As the air moves along, particles fall and settle on the plates. We assume that when the particles hit the plate, they stick there and remain on the plate – they are removed from the air. After some time, the device may get clogged, so it needs to be washed out. However, there are no moving parts, it does not require electricity, and it is simple and effective at removing particles from the air. Heavier and/or larger particles settle quickly, while lighter and/or smaller particles take longer to settle. Therefore we expect the removal efficiency of the device to depend on particle diameter and particle density.



Define __Grade Efficiency__ $E(D_p)$ = removal efficiency as a function of particle Diameter