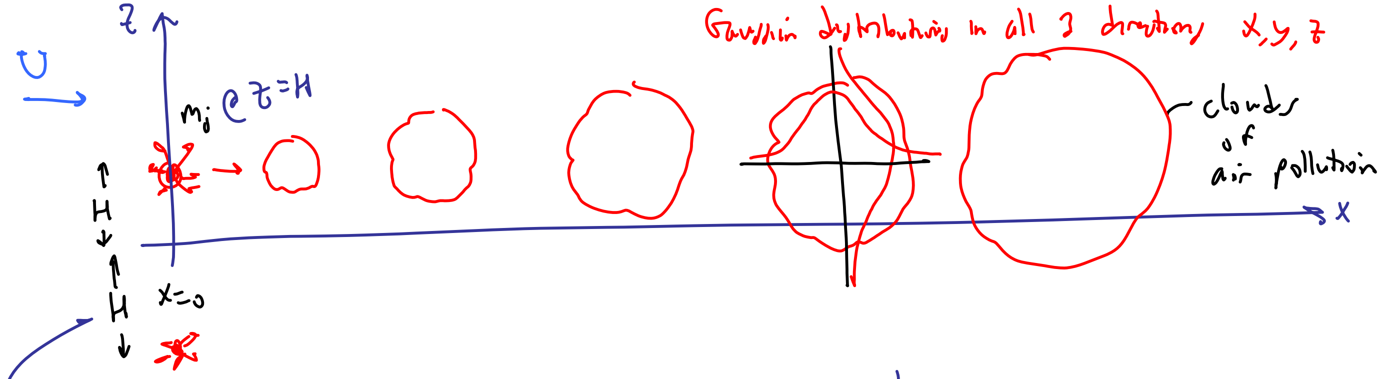
Today, we will:

- Discuss the **Gaussian puff diffusion model** (sudden burst of air pollution from a point)
- Discuss particle vs. steam plumes and how to distinguish them (Slides)
- Start talking about **particles** (sizes, shapes, terminology, classifications, etc.) (Slides)

GAUSSIAN PUFF DIFFUSION MODEL

- models a sudden burst of air pollution, like an explosion or a terror attack, or ruptured tank
- model as an instantaneous point source @ $t=0$

Let m_j = mass of species j released at time $t=0$ & @ Height H



If absorbing ground — we use one source as shown

If reflecting ground — we add an image source @ $z=-H$

Eq. is same as before, Gaussian diffusion eq., except we cannot ignore diffusion in x-direction & it is unsteady

Simplification → do a coordinate transformation → move with the puff

Use $x-Ut$ instead of x

Solution, Eq. is very similar to the smoke plume:

$$\boxed{C_j(x,y,z,t) = \frac{m_j}{\sqrt{2\pi}\,\pi\,\sigma_{x_i}\sigma_{y_i}\sigma_{z_i}} \exp\left\{-\frac{1}{2}\left[\left(\frac{x-Ut}{\sigma_{x_i}}\right)^2 + \left(\frac{y}{\sigma_{y_i}}\right)^2 + \left(\frac{z-H}{\sigma_{z_i}}\right)^2\right]\right\}}$$

PUFF DIFFUSION (1)

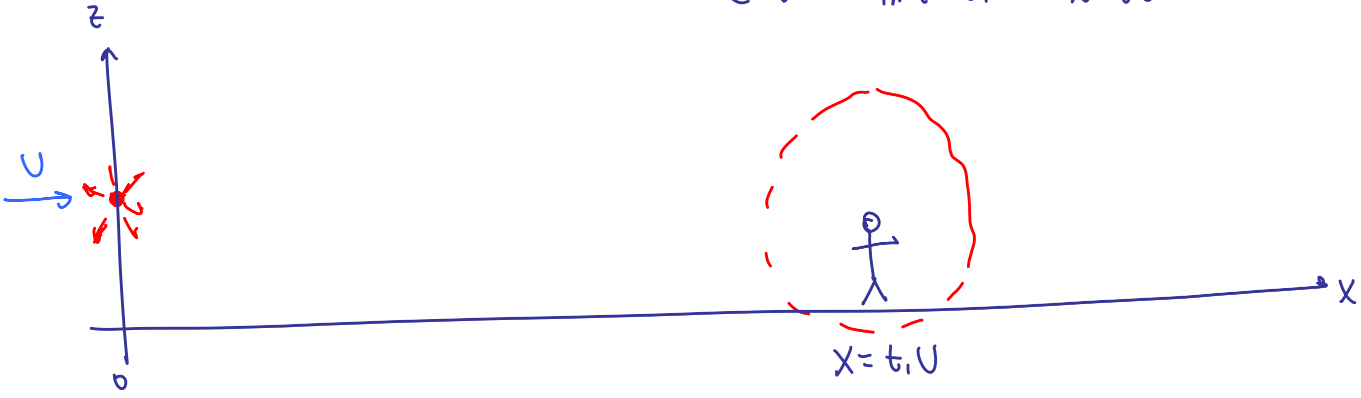
Instantaneous dispersion coefficients (subscript i)

$\{\sigma_{x_i}\}$ etc $= \{L\}$ in units of meters

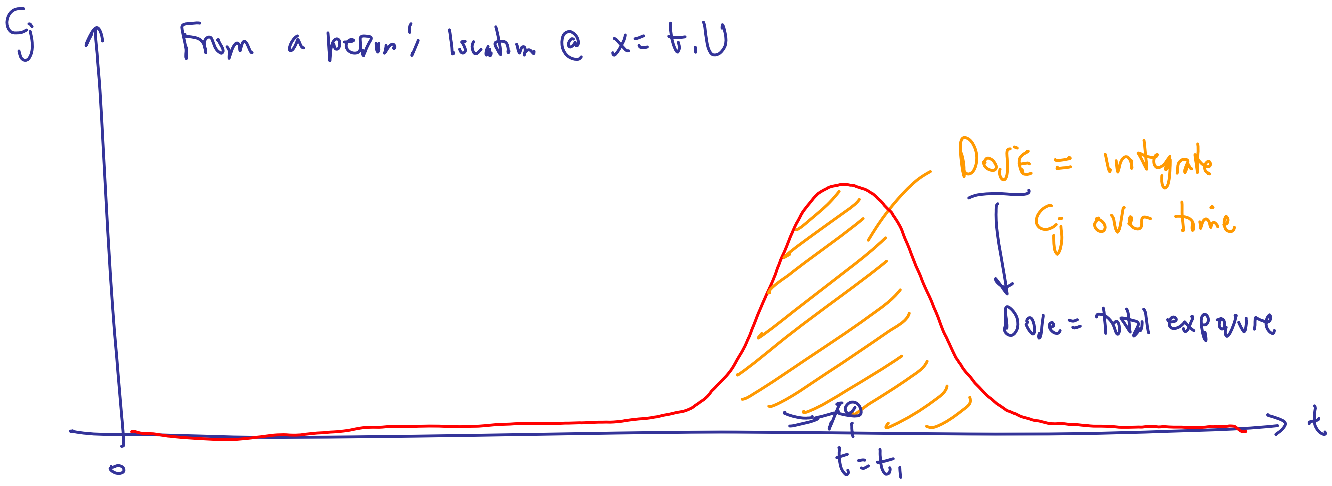
Not same as σ_y & σ_z from previously.

$\sigma_{x_i}, \sigma_{y_i}, \sigma_{z_i}$ → see Eq. sheet for these

@ some time t_1 $x - tU$ = coordinate



From a person's location @ $x = t_1 U$



Dose = integrate C_j over time → Dose = total exposure

Let D_j = Dose of j = $D_j(x,y,0)$ @ ground level [Consider z=0 from here on → ground level]

$$\boxed{D_j(x,y,0) = \int_{t=0}^{\infty} C_j(x,y,\overset{z=0}{0},t)\,dt}$$

= Dose of j that a person on ground is exposed to (2)

$$\{D_j\} = \left\{\frac{mass}{L^3}\cdot t\right\}$$

→ typ. units $\frac{mg\cdot s}{m^3}$ or $\frac{Mg\cdot s}{m^3}$

Plug (1) into (2) & integrate:

At ground level:

$z-H=-H$ when $z=0$

$$\boxed{D_j(x,y,0) = \frac{M_j}{\pi\,\sigma_{y_i}\,\sigma_{z_i}\,U}\exp\left\{-\frac{1}{2}\left[\left(\frac{y}{\sigma_{y_i}}\right)^2 + \left(\frac{H}{\sigma_{z_i}}\right)^2\right]\right\}}$$

☆ Gaussian Puff Diffusion, Absorbing Ground @ ground level

If $H=0$ (ground-level source)

If the ground is reflecting, add an image source @ $z=-H$

it Doubles the dose at ground level

Example: Gaussian puff diffusion

Given: A ground-level tank containing 10 kg of hydrogen cyanide (HCN) ruptures at a chemical plant early in the morning. The atmosphere is very stable, and a gentle breeze is blowing at $U = 1.5$ m/s. The ground absorbs the HCN on contact. Workers downwind of the explosion are exposed to the HCN.

To do:

(a) Estimate the dose of HCN that would constitute hazardous conditions for the workers.

(b) Predict the dose directly downwind. How far downstream is this hazardous?

Solution:

(a) Look up HCN's MSDS → ST = short term → 15-minute exposure

$$ST = 4.7 \text{ ppm} = 5 \text{ mg/m}^3$$

Dose considered hazardous is $D_{j,max} = \left(5 \frac{mg}{m^3}\right)(15 \text{ min})\left(\frac{60 s}{min}\right)$

$$= \boxed{4500 \frac{mg \cdot s}{m^3} = D_{j,max}}$$

(b) Table → "very stable atm" → $a = 0.02$ $b = 0.89$, $c = 0.05$ $d = 0.61$ $\left.\right\}$ $\boxed{\begin{matrix} \sigma_{y_i} = a x^b \\ \sigma_{z_i} = c x^d \end{matrix}}$

max @ y=0

H=0

$m_j = 10$ kg

$U = 1.5$ m/s

Equation for ground level dose, absorbing ground:

$$D_j(x,y,0) = \frac{m_j}{\pi U \sigma_{yi} \sigma_{zi}} \exp\left\{-\frac{1}{2}\left[\left(\frac{y}{\sigma_{yi}}\right)^2 + \left(\frac{\cancel{H}}{\sigma_{zi}}\right)^2\right]\right\}$$

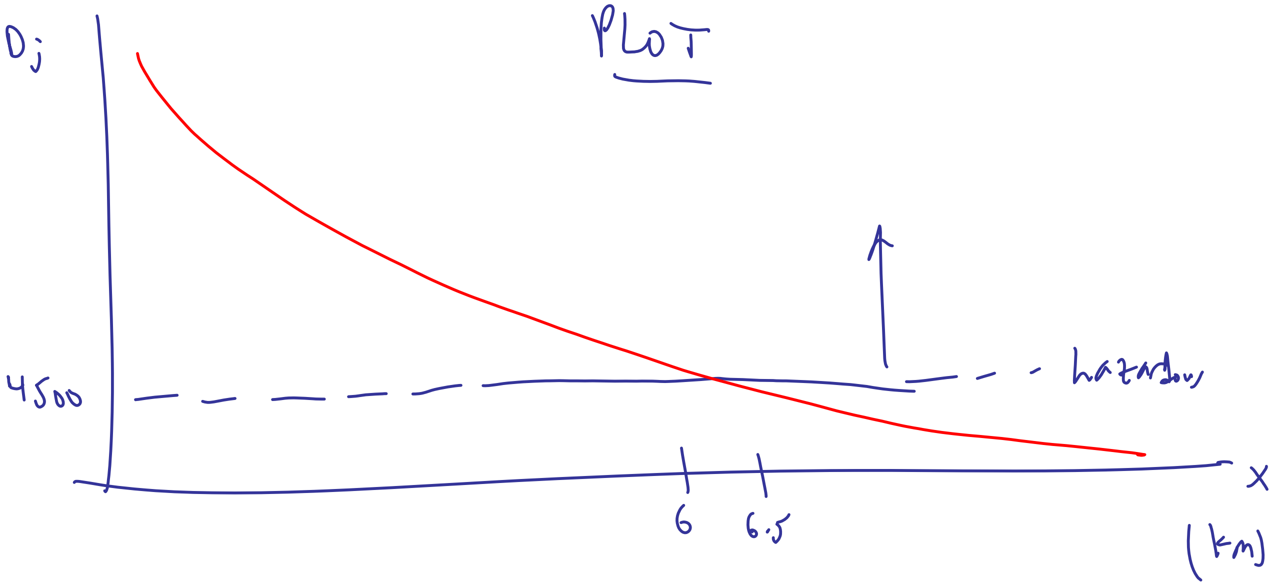
Table to be filled in during class:

x (km)	D_j (mg s/m^3)
1.0	67,100
1.5	36,500
2.0	23,700
2.5	17,000
3.0	12,900
3.5	10,200
4.0	8,300
4.5	7,030

x (km)	D_j (mg s/m^3)
-	-
5.0	6000
5.5	5200
6.0	4570
6.5	4050
7.0	3,620
7.5	2,970
8.0	2,970

HAZARDOUS

PLOT



☆ Answer – any worker closer than about 6.2 km is exposed to a "hazardous" level