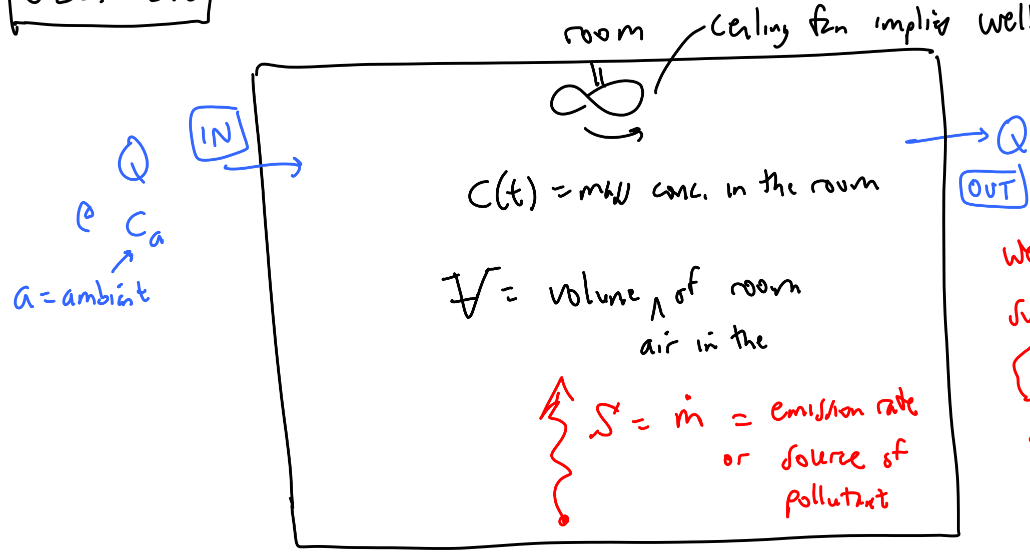
Today, we will:

- Discuss **Dilution Ventilation with Steady 100% Make-up Air** in **Section 5.3**
- Do some example problems
- Discuss **Dilution Ventilation with Unsteady Properties** in **Section 5.4**
- Do some example problems

$\boxed{\text{Sec. 5.3}}$ – DILUTION VENTILATION (THE WELL-MIXED MODEL)



We drop the j subscript in Ch 5 [consider only one species at a time]

Let C(0) = initial concentration in the room @ t = 0

$\boxed{\text{THIS IS IDENTICAL TO THE FLUX CHAMBER ANALYSIS OF CH. 4}}$ ✩

Same eq.'s ! Cons. of mass of the species

$$\boxed{\forall \frac{dc}{dt} = Q C_a + S - Q c}$$

- $\forall \frac{dc}{dt}$: rate of change of mass within the room
- $Q C_a$: rate of mass flow into the room by ventilation — "make-up air"
- S: rate of production or generation of mass [of the species]
- $Q c$: rate of removal of mass out of the room due to ventilation

Re-write eq. as:

$$\frac{dc}{dt} = \frac{Q C_a + S}{\forall} - \frac{Q}{\forall} c$$

or

$$\boxed{\frac{dc}{dt} = B - A c}$$

Standard form of a 1st-order ODE ✩

Solution: Since it is a standard 1^{st}-order ODE we can solve it

- If A & B are constant [Q, C_a, S are const.]
  [$\forall$ is always constant]

$\therefore$ Analytical sol'n (see Chap. 1)

$$\boxed{\frac{C_{ss} - c(t)}{C_{ss} - c(0)} = e^{-At}} \quad \star \quad \text{where} \quad \boxed{C_{ss} = \frac{B}{A}}$$

steady-state value of c

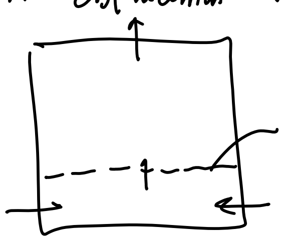
- In HVAC literature, they use

$$\boxed{N = \text{\# room changes per unit time}} \star$$

typically hours

$$\boxed{N = \frac{Q}{\forall}} \qquad \{N\} = \left\{\frac{\text{vol}/\text{time}}{\text{vol}}\right\} = \left\{\frac{1}{\text{time}}\right\} \rightarrow \left(\text{typ } \frac{1}{\text{hr}}\right)$$

For ideal displacement ventilation, if $N = \frac{1}{\text{hr}}$



new air acts like a piston, & pushes out the old air at a rate of 1 room volume per hour

For dilution ventilation (assume well-mixed) "# room changes" is a misnomer

After 1 hr (one "room change"), there is still smoke in the room!

[In theory, the smoke never completely leaves the room – it just decays exponentially]

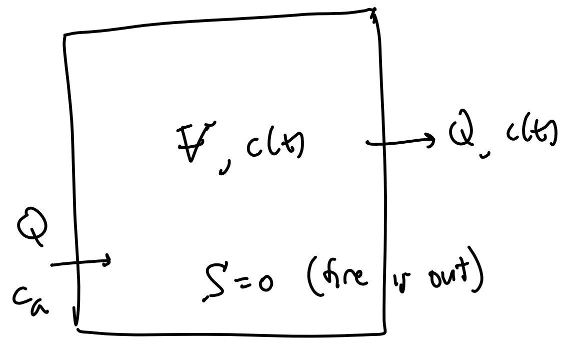
Example (Example 5.2 in text – When is it Safe to Enter a Room)

Given: A fire has occurred in a hotel room with volume V = 85. m^3. Immediately after the fire is extinguished, the mass concentration of hydrogen cyanide (HCN) is 10 g/m^3. The firemen blow "fresh" air into the room at Q = 28.3 m^3/min. Since there is some smoke outside the building, the "fresh" air actually has an ambient mass concentration of HCN equal c_a = 1.0 mg/m^3.

To do: Calculate how long the firemen need to wait before entering the room in order to stay below the STEL of HCN.

Solution: · MSDS → STEL = 5 mg/m^3

Given: $C(0) = 10 \frac{g}{m^3} = 10{,}000 \frac{mg}{m^3}$



· Since Q, S & c_a are constant, the analytical soln is valid:

$$C_{ss} = C_a + \frac{\cancel{S}^{\,0}}{Q} \rightarrow \underline{C_{ss} = C_a = 1.0 \ mg/m^3}$$

eq.:
$$\boxed{\frac{C_{ss} - C}{C_{ss} - C(0)} = \exp\left(\frac{-Qt}{\forall}\right)} \rightarrow \text{solve for } t$$

$$t = -\frac{\forall}{Q} \ln\left(\frac{C_{ss} - C}{C_{ss} - C(0)}\right) = 24 \text{ min.}$$

$$\boxed{\text{or} \approx 1/2 \text{ hr}}$$

Example 5.3 in text: (p. 357)

- Read it - it is a long problem.
  - Uses concepts from Ch. 1, 2, 3, 4, 5

dose rate & interaction with body, & ventilation rate

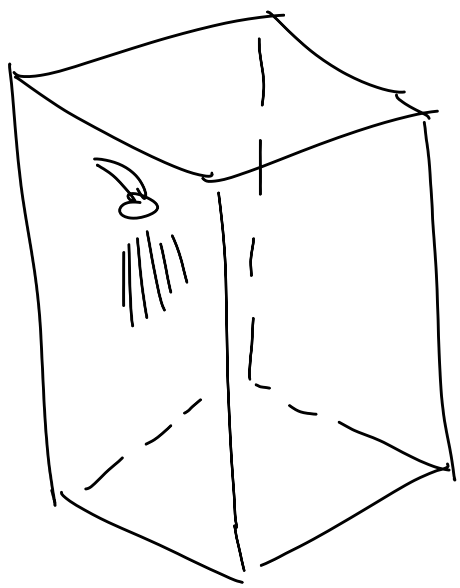
ventilation

1st-order eqs + conversions

PELs & exposure criteria

evaporation eqs

Taking a shower

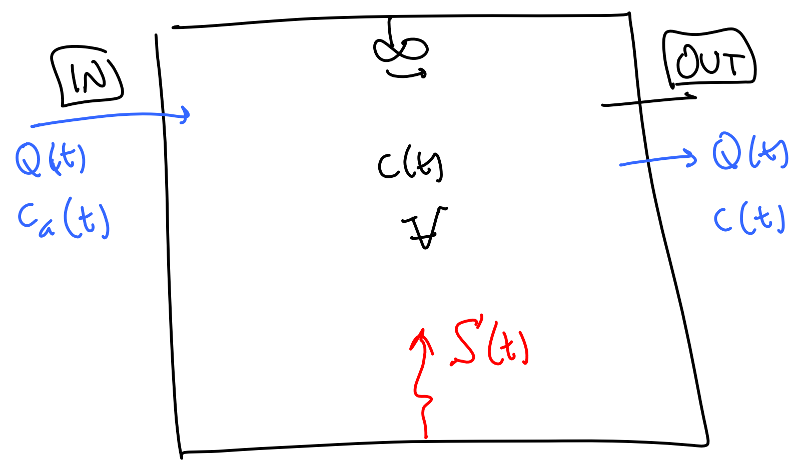


Concern about TCE contaminant in water → evaporate into the air in the shower stall & be harmful to breathe

Bottom line → concentration of TCE in the air is orders of mag. smaller than PEL

It is safe to take a shower!

SEC. 5.4 Well-mixed model, dilution ventilation, BUT non-constant parameters



Cons. of mass eq. is same as before but with non-constant coefficients

$$\boxed{\forall \frac{dC(t)}{dt} = Q(t)\,C_a(t) + S(t) - Q(t)\,C(t)}$$

How to solve?

Solve numerically → 1st-order ODE with non-constant coefficients

typically we Runge-Kutta technique

Two Categories of Unsteady Ventilation Problems

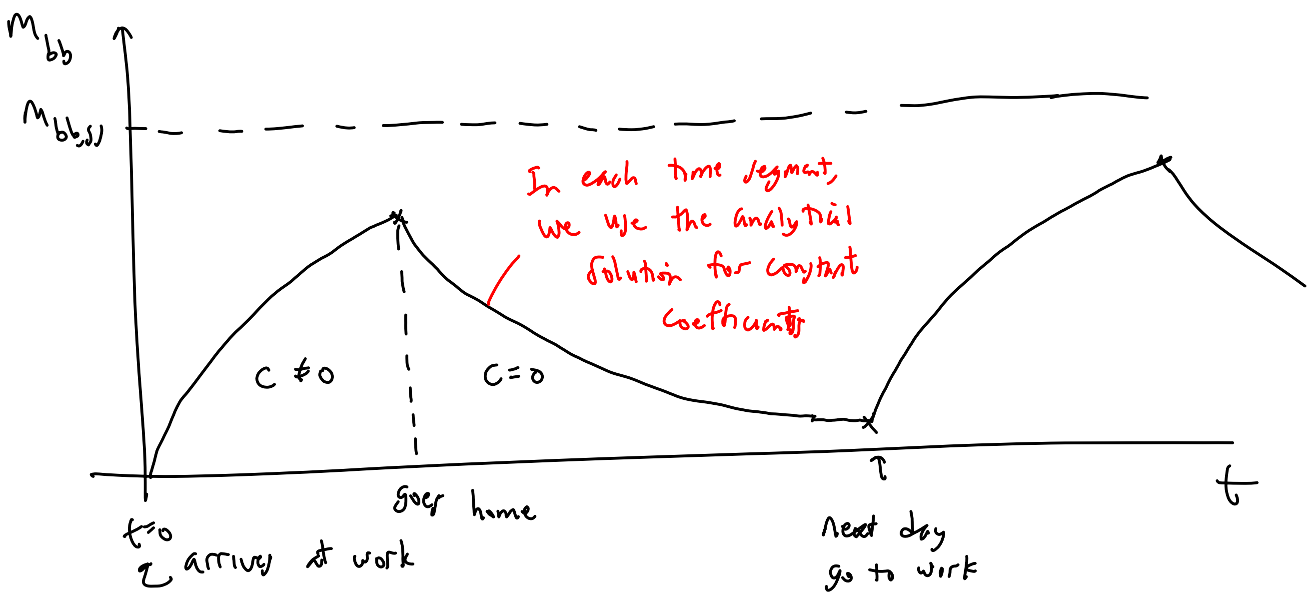
Category ①: If the parameters change in piece-wise fashion:

$0 < t < t_1 \rightarrow C_a, S, Q$ = some constant values

$t_1 < t < t_2 \rightarrow C_a, S, Q$ = constants but different values than the previous ones

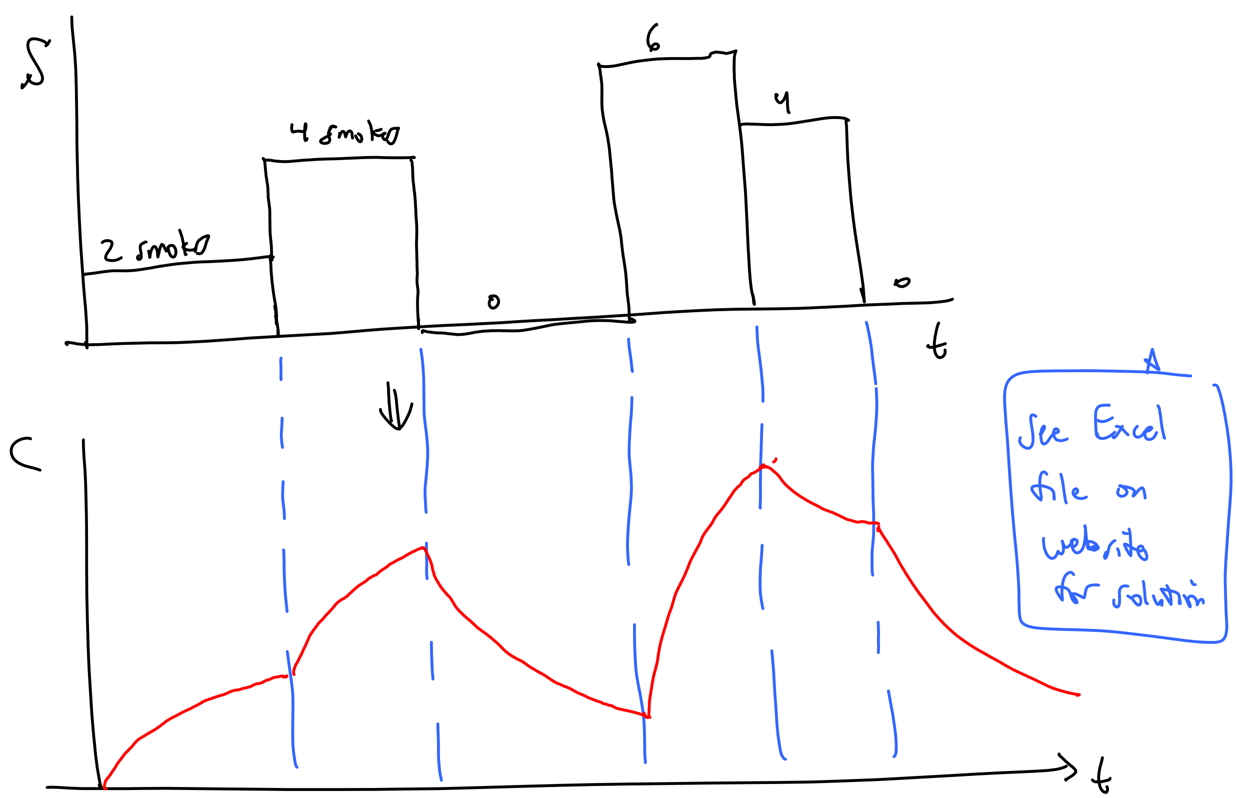
⋮

This is the same kind of problem as the body burden problems of Ch. 2 (M_{bb})



Eg. → See Example 5.4 in text

S is due to smokers in a room, & # of smokers changes



Category ② Unsteady Problems:

More general case → $Q(t)$, $S(t)$, $C_a(t)$ can be general functions of time

- I use Runge-Kutta in Mathcad
- You can use MatLab, Mathematica, EES, etc.

☆ $$\boxed{\frac{dc}{dt} = B - Ac \quad \text{but now } A \text{ \& } B \text{ are no longer constant but } A = A(t),\ B = B(t)}$$

Next time – I will show examples using Runge-Kutta (R-K) to solve these kinds of unsteady problems