# Examples of Lecture-by-Lecture Problems

- Demo only, updated 12/8/07
- Full list of questions will be provided by 1/22/07, first day of class
- All exam questions will be modeled after example problems
- Each class period will end with an example problem
- Each class period will begin with time devoted to answering questions related to problems/material from previous class

## Class 1: Air Pollution Overview

1. What are the species regulated under the NAAQS?
2. What are the NAAQS values for O3 and PM2.5?
3. What is the difference between a primary and secondary aerosols?
4. What are the health impacts of NAAQS pollutants?
5. What are the climate impacts of NAAQS pollutants?
6. Why is it useful to know the species mix of PM2.5?
7. What is the chemical notation for ozone?
8. In Wisconsin, ozone pollution is a problem in what season?
9. When people talk about the ozone hole, they are referring to ozone in what layer of the atmosphere?
10. What two emitted chemical groups react to form ozone pollution?

## Class 2: Atmospheric Composition Units

1. The World Health Organization issues guidelines for 8-hour ozone in mass concentration units.
   a. The WHO recommended value is 120 $ug/m^3$. **What is this in ppm?**

   b. This value is **higher than / lower than / same as (circle)** the US EPA National Ambient Air Quality Standard for ozone (8-hour average) of **___?**

2. Canada's 1-hour ozone standard is issued in mass concentration units.
   a. This value is 82 $ug/m^3$. **What is this in ppm?**
   b. This value is **higher than / lower than / same as (circle)** the US EPA National Ambient Air Quality Standard for ozone (8-hour average) of **________________ppm?**
   c. What are the other species are governed by the NAAQS (list all compounds. You do not need to list their associated regulatory limit).
3. Jacob, problem 1.3
4. Based on the PM speciation data from the EPA/NARSTO 2003 PM Assessment - shown in lecture - what is the mass concentration of sulfate aerosol in Mexico City?

5. What information would you need to know to calculate the column density of CO?
6. Why aren't aerosol concentrations often expressed in terms of mixing ratios?
7. What is .06 ppb $NO_2$ in micrograms (ug) per $m^3$? (1 g = $10^6$ ug) Consider 1000 hPa pressure, 0 C temperature.

….

## Class 6: Lifetimes & Dispersion

1. Consider a 100 ug puff of carbon monoxide released into the atmosphere with an atmospheric lifetime of 1 week.
   a. Write the equation that describes the concentration of CO in the puff (X) as a function of time (t, in seconds).

   b. What is the concentration in the puff after 3 weeks?

2 Consider a passive tracer X with a lifetime of 8 hours. Imagine the release of a puff of air from a power plant, which contains a concentration of X of 5000 molecules/$cm^3$ upon release from the stack. As the puff moves away from stack, the concentration of X maybe described with the equation:

$$d[X]/dt = -k[X]$$

a. What is the value of k?

b. What is the concentration of X in the puff after 1/2 day?

c. If the puff were carried eastward by winds at 5 m/s, how far would the puff have traveled by the time the concentration is 1000 molecules/$cm^3$?

d. Now, imagine the air above the power plant (forget the traveling puff). Emissions of X from the power plant are 0.02 molecules/($cm^3$s). Ignoring transport, what is the steady-state concentration of X in the air above the power plant?

….

## Class 9: Turbulence

1. Consider measurements of $SO_2$ and vertical velocity $w$ taken every second at an observation tower located 50 m above the surface. Imagine you had analyzed these measurements to calculate the following quantities:

$\overline{w}$ = -1 m/s

$\overline{SO_2}$ = 50 ug/m$^3$

$\overline{w'SO_2'}$ = 100 ug/(m$^2$s)

a. What is the advective flux?

b. What is the turbulent flux?

c. What is the total flux?

d. Draw the time-series of *w* and $SO_2$. Label what on your illustration is known, and label what (if anything) you had to assume.

e. Assume the time-mean vertical concentration from the surface (z=0) to .1 km altitude (z=100 m) of $SO_2$ may be described as $SO_2 = 2*(z/10 - 10)^2$, where *z* is in m and $SO_2$ is in ug/m$^3$. Plot the concentration as a function of height from the surface to 100 m

f. What is the vertical $SO_2$ gradient at the height of the observation tower?

g. What value of $K_z$ would be appropriate to estimate the observed turbulent flux with a Fickian diffusion parameterization (note the units)?

h. Redraw your concentration plot (from e) with the direction of turbulent diffusion added to the chart (as an arrow).

2. If I'm only interested in the monthly average inflow of $PM_{2.5}$ from Illinois to Wisconsin, could I just take monthly mean $PM_{2.5}$ at the WI-IL border, and multiply this mean concentration by the monthly mean south-to-north winds?"

## Class10: Continuity Equation, Part I

1. *Note: for the following question, assume a Fickian diffusion form for turbulent flux throughout*. Recall that the Eulerian form of the Continuity Equation is

$$\frac{\partial n}{\partial t} = -\vec{\nabla} \bullet \overline{(n\vec{U})} + P - L$$

a. Write the z component of this equation (recall that the z component of the wind velocity is denoted *w*). Write all terms (other than P and L) in terms of $\overline{n}$.

b. For the following parts of the question assume that

- at time t = 0, n varies from z=0 to z=10 in the form $\mathbf{n(z) = 3z^3}$
- z in meters; n in molecules/$m^3$
- there is a constant downward wind *w* at 1 m/s
- Consider the 0 to 10 m vertical domain broken down into discrete grids, each 1 m thick.
- Perform the following calculations on the grid near the center of the domain running from 4 m to 5 m (i.e. calculate values at 4.5)
- No chemical production and loss

**Plot n across the domain AND calculate n(t=0) in our box of interest**

c. Considering only advective flux, calculate dn/dt at time 0 in our box.

d. Considering only turbulent flux, and K = .2, what is dn/dt at time 0 in our box? (Reminder: look closely at your answer in part *a*)

e. What is n(t=0.5 seconds) in our box, including change from both advective AND turbulent flux terms? (use simple backward Euler scheme)