1.061 / 1.61 Transport Processes in the Environment
Fall 2008

Problem 1

Two airplanes are conducting tests to estimate the coefficient of diffusion in a stagnant atmosphere. The first airplane, flying 1 km above the earth's surface, instantaneously releases 1 kg of trace gas. The second airplane flies through the cloud 60 minutes later and measures a maximum concentration of 0.03 mg/L within the cloud.

Estimate the coefficient of diffusion within this region of the atmosphere.

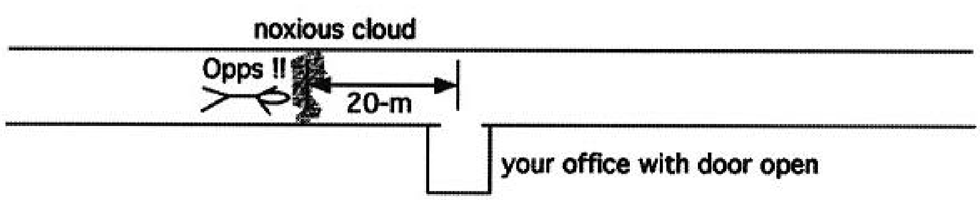
Hint 1 Can you assume uniform concentration in any direction?

Hint 2 What assumption can you make about the air currents?

Hint 3 What assumption must you make about the coefficient of diffusion?

Problem 2

A friend of yours is coming to meet you at your office, which is located mid-way along a very long (100 m) hallway. In preparation for a small prank, he is carrying a vial containing 10-g of a noxious smelling gas. He trips 20-m before reaching your office door, and the vial breaks. The gas rapidly mixes vertically and horizontally within the hallway, which is 2-m wide and 3-m high. The human nose will detect the gas at concentrations greater than $10 - \mu g/l$. Assume an isotropic diffusion, $D = 0.05\, m^2/s$.



(a) What governing equation describes the evolution of gas concentration in the hall?

(b) At what time after the spill do you smell the gas?

(c) When does the smell, as perceived by humans, disappear from the hallway?

Problem 3

A drop of red and a drop of blue dye, each 1 mg, are released 10 cm apart into a layer of stagnant fluid between two plates. The plates are $1\, m \times 1\, m$ in area and are $5\, mm$ apart. The dye drops are released at the center of the plate area and mix rapidly across the fluid layer, i.e. between the plates. The molecular diffusion of the dyes are: $D_{red} = 10^{-5}\, cm^2 s^{-1}$ and $D_{blue} = 4 \times 10^{-5}\, cm^2 s^{-1}$.

The human eye can detect the color of the dye at concentrations of 10 g/L. No reactions occur between the two dyes, but at locations where the two dyes coexist and are both above the visible threshold, the mixture will appear purple.

(a) While both clouds are fully visible ($C > 10\, g/L$), which cloud appears larger, and by how much?

Hint 1 Make a sketch that defines the diameter of each cloud

(b) At what time and at what location will the two dye clouds first appear to touch?

Hint 2 Simplify the governing equations with assumptions

Hint 3 Write the mathematical criterion for the condition when clouds first touch

(c) At what time will the line connecting the release points be completely purple?

Hint 4 Define a mathematical criterion for this to occur