CE 111: Environmental Engineering MIDTERM EXAM #2 3 November 2010

1. Concepts in environmental transport (4 points; 1 each)

Provide a brief answer to each of the following questions to demonstrate your knowledge and understanding of environmental transport phenomena.

(a) Write an expression for the relationship between one-dimensional advective flux and species concentration. Define your terms and provide appropriate units for each.

(b) Turbulent transport is often modeled in a way that parallels Fick's law: $\overline{J_{t_y}} = -\varepsilon \frac{d\overline{C}}{dy}$.

Define the symbol ε and provide an appropriate set of units.

(c) Drag on a particle is governed by two fluid properties: density and viscosity. What is the dimensionless number that determines which of these properties contributes strongly to drag?

(d) In studying projectile motion, one commonly starts with Newton's law: $F = m\,a$. In environmental transport, the basis for analyzing particle settling is to solve $F = 0$. Why is it acceptable to neglect acceleration when studying particle settling in environmental fluids?

2. Transformations in flow reactors (8 points; 4 each)

Fluid flows through a reactor of volume $V = 100\ \mathrm{m}^3$ at rate $Q = 25\ \mathrm{m}^3\ \mathrm{h}^{-1}$. Fluid contains three species of interest (A, B, and C). These are the steady concentrations at the inlet of the reactor: $[\mathrm{A}]_{\mathrm{in}} = 5$ mM, $[\mathrm{B}]_{\mathrm{in}} = 10$ mM, and $[\mathrm{C}]_{\mathrm{in}} = 15$ mM. Within the reactor, this reaction occurs:

$$\mathrm{A} + \mathrm{B} \rightarrow \mathrm{C}$$

The reaction is first order in [A] and zeroth order in [B] with rate constant $k = 0.25\ \mathrm{h}^{-1}$.

(a) Compute the concentrations of [A], [B], and [C] at the outlet of the reactor, assuming that the reactor is a perfect CMFR.

(b) Repeat (a) for the case in which the reactor is a perfect PFR.

3. Transient response in reactors (8 points; 4 each)

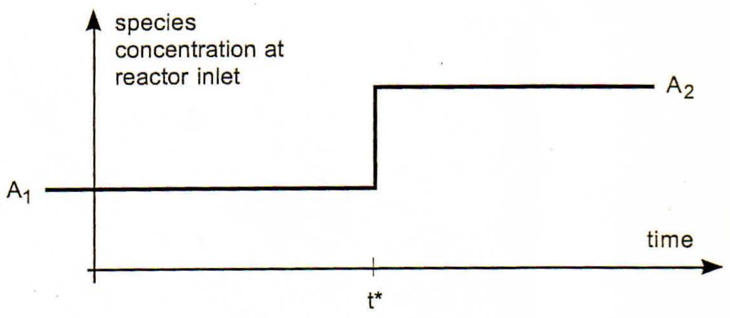

Figure 3. Time-dependent concentration of species A at the reactor inlet.

Fluid flows through a reactor of volume V at flow rate Q. Species A in the fluid undergoes first-order decay with a rate constant k. The species concentration at the reactor inlet, $[\mathrm{A}]_{\mathrm{in}}$ varies with time as depicted in Figure 3: for all times $t < t^*$, the value is $[\mathrm{A}]_{\mathrm{in}} = A_1$; for all times, $t \geq t^*$, the value is $[\mathrm{A}]_{\mathrm{in}} = A_2$. For cases (a) and (b), sketch the time-dependent species concentration, [A], at the outlet of the reactor. [*Hints*: The time scale should be sufficient to show the full dynamic shift from before t^* to the ultimate steady condition after t^*. The concentration axis should be clearly marked with appropriate initial and final concentrations. The time scale should clearly indicate t^* and any other relevant characteristic time scales.]

(a) The reactor is an ideal CMFR.

(b) The reactor is an ideal PFR