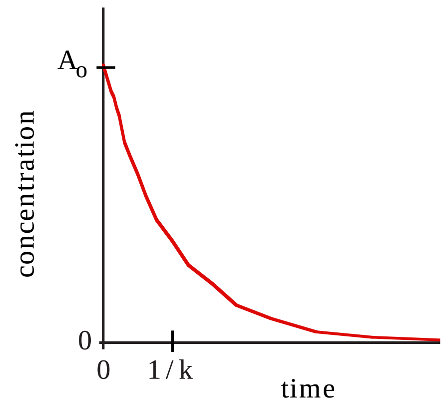
PICTURING POLLUTION

Scoring — (a)-(e) 2 points each

For each of the situations described, sketch a diagram depicting the pollutant concentration as a function of position or time, as requested. To receive full credit, the shape of your trace must be correct. You must also label the coordinate axes with (i) the dependent or independent variable represented, and (ii) appropriate values to indicate concentration scales, length scales, and time scales as appropriate.

Example: A species undergoes first order decay in a batch reactor. Its concentration at t = 0 is A_o. The rate constant is k. Sketch the concentration vs. time.
Answer: See sketch at right.



(a) An ideal, completely mixed flow reactor (CMFR) contains fluid volume V and balanced inlet and outlet flows at rate Q (volume per time). For all time $t < 0$, a contaminant of concern is absent from the reactor. At $t = 0$, the contaminant concentration in the inlet flow suddenly rises to C* (mass per volume) and remains at that level indefinitely. The contaminant is nonreactive. Sketch the contaminant concentration at the reactor outlet as a function of time for $t \geq 0$.

(b) Repeat (a) for the case that the contaminant decays within the reactor by a first-order process with rate constant k (per time).

(c) Repeat (b) for the case that the vessel is an ideal plug-flow reactor (PFR).

(d) Now consider a batch reactor in the shape of a right-circular cylinder. Its axis is aligned with gravity, so the cross-section in a horizontal plane is circular. The volume of the reactor is V and its height is H. At time t = 0, the reactor is filled with a fluid that contains a total number, N*, of identical particles. After the reactor is filled, it is sealed and the fluid rapidly becomes motionless. The particles have a settling velocity v_s. Consider time $t^* = (1/2) \times (H/v_s)$. Let z be the vertical coordinate, defined so that $0 \leq z \leq H$ represents the vertical extent of the reactor. Sketch the number concentration of suspended particles as a function of height z in the reactor at time t*.

(e) Consider a batch reactor with a volume of 3 L. At time t = 0, the reactor is filled (and then sealed) with V_w = 1 L of water that initially contains no dissolved oxygen and V_a = 2 L of air that has oxygen at a partial pressure of P_{O2} = 0.21 atmospheres. Oxygen is exchanged between air and water as described by the two-film model with a mass-transfer coefficient of k_{gl} = 0.1 m/h. The air-water interface area is A = 100 cm^2 = 0.01 m^2. The Henry's law constant for oxygen in water is K_H = 0.00138 M atm^{-1}. Sketch the molar concentration of dissolved oxygen in water versus time in the reactor.