1. Transient response of reactor models (6 points; 3 each)

(a) Contaminated water flows through an ideal PFR of volume $V = 100\ m^3$ with flow rate $Q = 50\ m^3\ h^{-1}$. Within the reactor, the contaminant undergoes first-order decay with a rate constant $k = 0.7\ h^{-1}$. For all time $t < 0$, the inlet concentration is $C_{in} = 150\ \mu g\ m^{-3}$. Suddenly, at $t = 0$, the inlet concentration decreases to $C_{in} = 50\ \mu g\ m^{-3}$ and remains at this level indefinitely. Sketch the outlet concentration, C, as a function of time for $0 \le t \le 4$ h. Properly label axes.

(b) Repeat (a) for the case of an ideal CMFR.

2. Sedimentation for particle control in drinking water treatment (6 points)

A conventional sedimentation basin is designed to remove particles from water. In plan view, the basin is rectangular. Its dimensions are 25 m long × 6 m wide × 3 m deep. Water flows through (parallel to the long dimension) at a speed of 600 m d^{-1}.

(a) Evaluate the overflow rate for this sedimentation basin, in units of m/d. (1 point)

(b) What is the critical settling velocity for this sedimentation basin, in units of cm/s? (1 point)

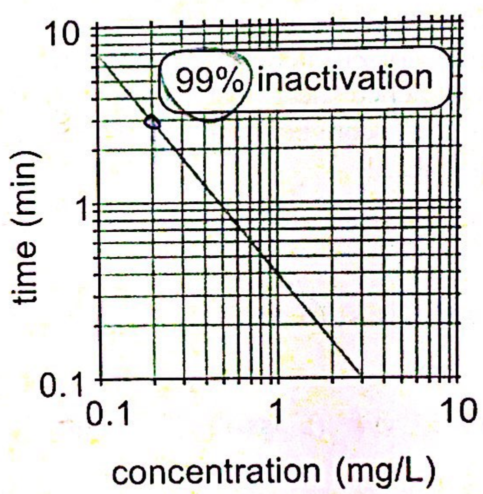
(c) Consider particles with the density of soil grains (~ 2.5 g/cm^3). Calculate the particle diameter for which the removal efficiency in this unit is 75%. (4 points)

3. Disinfection performance in drinking water treatment (6 points; 3 each)

The figure shows the time required for 99% inactivation of *E. coli* by chlorine in a batch reactor. Use this information for the following problems. Consider the disinfection stage of a drinking water treatment plant. Assume that Chick's law applies.

(a) The treatment unit is an ideal PFR. The chlorine concentration is 0.2 mg/L. What hydraulic detention time ($\theta = V/Q$) is required to achieve 99.9% inactivation?

(b) The treatment unit is an ideal CMFR. The chlorine concentration is 3 mg/L and the hydraulic detention time (= V/Q) is 5 minutes. What is the expected inactivation level of *E. coli* in this treatment unit? Express your answer in two ways: (i) % inactivation; and (ii) the value of n corresponding to n-log inactivation.



4. Characteristic response time for lake following contaminant spill (2 points)

A mass M of a volatile, reactive contaminant is suddenly spilled into lake of volume V and surface area A, throughout which it becomes rapidly mixed. The contaminant escapes from the lake water by three mechanisms: (a) interfacial mass transfer, as described by the two-film model with mass transfer coefficient, k_{gl}, (b) first-order chemical decay with rate constant, k; and (c) along with water flowing out of the lake and into a river at volumetric rate, Q. In terms of some or all of these parameters (i.e., M, V, A, k_{gl}, k, and Q) what is the characteristic time for the lake water to be restored to its pre-spill condition with regard to this contaminant? [*Hint*: It is reasonable to assume that the contaminant is absent from the air above the lake.]