**NAME**

GROUND RULES: This is a closed-book/closed-note exam, except that you are permitted two sheets of notes. Do your work on the paper provided. After the exam, staple your work to this exam sheet. Please be sure that your name is written on each page you submit. Also, please be sure that the problem number and your answer are clearly indicated.

The total score possible is 24 points, and the time allowed is 50 minutes. Use the time wisely. Good luck!

REMINDER: Read the questions **carefully**, and be certain you are responding appropriately.

HINTS:

(1) If you don't understand a question, state what you think the problem is asking for, then answer that.

(2) If you seem to be missing an important piece of information, assume a reasonable value, state your assumption, and proceed.

(3) Partial credit is granted, but only if your work can be understood (and your thinking is reasonable).

PROBLEM #1 (9 possible) _____

PROBLEM #2 (9 possible) _____

PROBLEM #3 (6 possible) _____

TOTAL SCORE (out of 24) EQ \X( )

1. NONREACTIVE TRACERS IN REACTOR SYSTEMS (9 points; 3 points each)
Water flows at a constant rate Q (volume per time) through a reactor system. At the inlet, the concentration of a nonreactive, nonvolatile tracer undergoes a time-dependent change. Three cases (a-c) are to be considered. For each case, the time-dependent inlet concentration and the details of the reactor system are specified. S**ketch the time-dependent concentration of the tracer at the reactor outlet**. Assume that the tracer is absent from the reactor system at t = 0. Also assume that the reactors depicted are either ideal CMFRs or ideal PFRs. [*Hint*: For full credit, your answer should show the correct qualitative shape and have the concentration and time scales properly indicated, as in the example.]

*Example:*

**(a)**

**(b)**

**(c)**

2. SEDIMENTATION (9 points; 3 each)

(a) A generic treatment process is depicted in the schematic at the right. (As usual, Q represents a fluid flow rate [volume/time], $C_{in}$ is the inlet contaminant mass concentration [mass/volume] and C is the outlet contaminant mass concentration [mass/volume].) Using these parameters, write a definition of the removal efficiency of the treatment process.

(b) Consider sedimentation as a specific treatment process. A rectangular sedimentation basin is depicted at right. Water flow is laminar and uniform throughout the basin. In terms of the parameters shown, write one or more expressions that give the particle removal efficiency of this process. Consider particles that have a single specific settling velocity, $v_s$. [*Caution:* Be sure that your answer is valid for all possible values of $v_s$.]

(c) Now consider sedimentation in an aqueduct that can be modeled as a plug flow reactor. In this case, the flow is not laminar. Rather, turbulent mixing maintains uniform pollutant concentrations throughout any vertical cross-section. The turbulence does not significantly influence transport in the direction of net water flow. Consider suspended particles that have a settling velocity $v_s$. Assume that once a particle settles to the bottom, turbulence will not cause resuspension. Given the inlet concentration, $C_{in}$, the settling velocity, $v_s$, and the geometric and flow parameters shown in the figure, derive an equation for the outlet particle concentration, C.

3. CONCEPTS IN WATER QUALITY ENGINEERING (6 points, 1 each)

Answer each of the following questions. No more than one sentence is required in each case, sometimes less.

(a) In water treatment, what is "backwashing?"

(b) Analysis of a river using a DOsag curve shows a value of $DO_{min}$ that is considered too low. What pollutant (or pollutant class) needs to be discharged at a lower rate to fix this problem?

(c) What is an "outfall?"

(d) According to the Surface Water Treatment Rule, drinking water treatment systems must filter their water if they use surface water or ground water under the direct influence of surface water. Consider a drinking water treatment system using ground water that is not under the direct influence of surface water. Why is it logical that filtration is not required in this case?

(e) What advantage does a multimedia filter offer over a conventional rapid-sand filter?

(f) In desalination of seawater to make drinking water, what is the key advantage of reverse osmosis as compared to distillation?