CE 111: Environmental Engineering MIDTERM EXAM #2 6 November 2013

Your Name:

Groundrules

- This is a closed-book exam; you are permitted two sheets of notes.
- Do your work on the paper provided. After the exam, submit your work and this exam sheet.
- Please be sure that your name is written on each page you submit. Also, please be sure that the problem and your answer are clearly indicated.
- You are expected to use a calculator. But you are not allowed to use a personal computer. Nor are you permitted to use any device capable of wireless communication.
- To receive proper credit, you must not only show the correct results, but also clearly indicate the work leading up to the results. For problems that require analysis, points may be deducted if the grader cannot follow the logical flow from problem statement to answer.

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

Hints

- If you seem to be missing an important piece of information, assume a reasonable value, state your assumption, and proceed.
- Partial credit is granted, but only if your work can be understood (and your thinking is reasonable).
- The multipart problems do not need to be solved in the order presented.
- See attached sheet (inside covers of text) for potentially relevant information.
- The total score possible is 20 points, and the time allowed is 50 minutes. Use the time wisely.
- Good luck!

#1 (4 possible) _ 3 (6 poss

#4 (4 possible) _

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1. Elements of environmental engineering (4 points; 1 each)

(a) We have encountered the expression $J_d = -D\, dC/dx$. What are the units or dimensions for D?

(b) When the particle Reynolds number is less than 0.3, what fluid property makes the dominant contribution to drag?

(c) Consider a municipal drinking water treatment plant that includes a deep-sand filter. What two indicators does the operator use to decide when to clean the filter?

(d) A reservoir has a surface area A and water volume V. A volatile contaminant is accidentally spilled into the reservoir at time $t = 0$. The contaminant escapes to the atmosphere at a rate described by the two-film model, $J_{gl} = -\, k_{gl}\,(C_s - C)$. What is the characteristic time for the contaminant to escape from the reservoir by volatilization? Express your answer in terms of the parameters that appear in this problem statement.

2. Reactor sizing (6 points; 3 each)

A water flow rate of $Q = 0.5$ m^3 h^{-1} is to be treated in a reactor so that the contaminant concentration in the treated water is reduced from an inlet concentration, $C_{in} = 20$ µg m^{-3}, to an outlet concentration, $C = 1$ µg/m^3. Within the reactor, the contaminant undergoes first-order decay, with a rate constant $k = 0.2$ h^{-1}.

(a) What reactor volume, V, is necessary to achieve the treatment goal if the process is configured as a CMFR?

(b) What reactor volume, V, is necessary to achieve the treatment goal if the process is configured as a PFR?

3. Particle control by sedimentation (6 points; 3 each)

In this problem, you are to evaluate the removal efficiency of a sedimentation basin for 20 µm soil particles (density, $\rho = 2.5$ g cm^{-3}) suspended in water. The settling velocity of such particles is $V_t = 0.033$ cm/s = 1.2 m/h.

(a) The sedimentation basin is rectangular with these dimensions: length (L) = 30 m, width (W) = 8 m, height (H) = 4 m. Water flows through the basin at a volumetric rate of $Q = 600$ m^3/h. The water flow is ideal: steady, laminar, and uniform, with the velocity vector oriented horizontally and parallel to the basin length, L. Given these conditions and assuming ideal performance, what is the efficiency of this unit for removing 20 µm particles from the water?

(b) Consider a tank of the same dimensions as in part (a), processing water at the same flow rate. However, now assume that the sedimentation basin is well described as an ideal, completely mixed flow reactor (CMFR). What is the efficiency of this unit for removing 20 µm particles from the water? [*Hint*: You may assume that the stirring maintains well-mixed conditions throughout the bulk of the water, but does not resuspend particles from the bottom.

4. Reactor transient response (4 points)

A plug-flow reactor is operated with a hydraulic detention time of $\theta = 2$ h. The inlet stream contains a contaminant whose concentration rises and falls following the triangular pattern shown in the figure below. Within the reactor, the contaminant decays by a first-order process with rate constant, $k = 0.5$ h^{-1}. Plot the contaminant concentration at the reactor outlet versus time. The concentration and time axes should be specifically labeled with appropriate numerical values.