PRACTICE EXAM

~~NAME:~~ ______________________

CE251 Exam 1 Environmental Physics. April 4, 1997.

100 points total. Closed book and notes.

NOTE: SKIP one of the following problems: 1, 2a, or 2b.

You must clearly indicate which problem you are skipping by drawing an X across it. Otherwise, you will be graded on the first two (1 and 2a).

1. (20 points) The hydraulic gradient in a groundwater aquifer is 0.0030. The depth of the aquifer is 100 m, the horizontal width of the region through which groundwater flows is 5 km, the hydraulic conductivity of the aquifer material is 30 m/day, and the porosity is 40%. What is the volumetric flow rate of water through the aquifer? Report your answer in units of m^3/day.
(This problem may be selected as the one you skip.)

The purpose of these posted past-exam-questions is:

1) to give you a preview of the types of questions to expect, and

2) to allow you to test yourself if you wish. (Do the problem, then compare your answer to the one shown here)

Volumetric flow rate of water = 4.50×10^4 m^3/day

2. A 1.0×10^6 gallon reactor is used in a sewage treatment plant. The influent concentration is 100 mg/L, the effluent concentration is 25 mg/L, and the flow rate through the reactor is 500 gallons/min.

   (a) (20 points) What is the first-order rate constant for decay of BOD in the reactor? Assume that the reactor can be modeled as a CSTR. Report your answer in units of hr^{-1}.
   (This problem (2a) may be selected as the one you skip.)

(b) (20 points) Assume that the reactor should be modeled as a PFR with first-order decay, not as a CSTR. In that case, what must the first-order decay rate constant within the PFR reactor? (The problem conditions stated at the start of problem 2 still apply.)
(This problem (2b) may be selected as the one you skip.)

First-order decay rate constant within PFR = 0.042 hr^{-1}

(c) (5 points) It has been determined that the outlet concentration is too high, and that as a result, the residence time in the reactor must be doubled. Assuming that all other variables remain constant, what must be the volume of the new reactor? (The problem conditions stated at the start of problem 2 still apply.)

(f) What fraction of the initial concentration of A is left after 30 days? (Still assume that B = constant $= 5 \times 10^{-5}$ M, and k = 0.5 min^{-1} M^{-1}.)

Fraction of initial concentration of A left after 30 days = ______________________

4. (15 points) Each of the following problems or situations can be solved using a mass balance approach. In each case, determine whether the mass balance would be steady-state or non-steady-state, and whether it would be conservative or non-conservative, and circle the correct answers.

(a) Chlorofluorocarbons (CFCs) are inert in the troposphere (the lower atmosphere). The only sink for CFCs in the troposphere is slow movement of air carrying CFCs from the troposphere to the stratosphere (the next higher region of the atmosphere), where they destroy the stratospheric ozone layer. To prevent this destruction, CFC production has been nearly halted. Assuming that there are no longer any emissions of CFCs into the atmosphere, how long will it take concentrations of CFCs in the troposphere to drop to 1/10 of their current level?

This problem is

steady-state **non-steady-state**

and the compound is

conservative **non-conservative**

(b) A leaking exhaust pipe is sending carbon monoxide (CO) into the interior of a car at a rate of 2.0 g/s. Given the rate at which clean air enters the car through the ventilation system and the (equal) rate at which interior air exits the car, determine the concentration of CO in the car after it has been driven for a long time. CO is inert.

This problem is

steady-state **non-steady-state**

and the compound is

conservative **non-conservative**

(c) A VOC incinerator is used to destroy an organic pollutant produced in a chemical synthesis. The residence time in the incinerator is 0.001 s, and the chemical is destroyed in the incinerator with a first order rate constant of 4.6×10^{3} s^{-1}. What is the concentration of the pollutant in the incinerator exhaust?

This problem is

steady-state **non-steady-state**

and the compound is

conservative **non-conservative**

Type 4

NAME: ____________________

CE251 Exam 1 Environmental Physics. January 8, 1997.

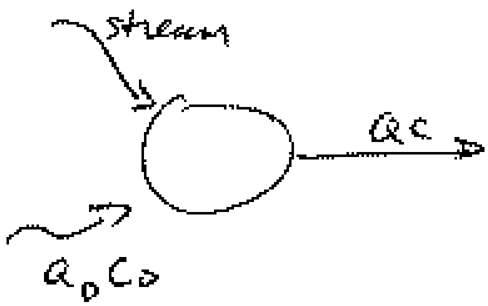
100 points total. Closed book and notes.

1. A pond, which can be modeled as a CSTR, has two inputs: a clean stream ($Q_s = 11$ m^3/s) and a pollutant discharge ($Q_d = 1$ m^3/s, $C_d = 6$ mg/L). There is a single river exiting the lake. The lake volume, V, is constant at 2.0×10^6 m^3, and the pollutant is not destroyed chemically or biologically in the lake. All flows and concentrations have been constant for the past year.

   (a) (10 points) (1) Write a mass balance for the mass of pollutant in the lake. **Use symbols (Q, V, C, etc.), rather than the numerical values, in your equation.**
   Simplify your final equation by eliminating all terms which are equal to zero, and circle your final mass balance equation.

   $\emptyset = Q_d C_d - Q C$

   (2) Draw a diagram of the situation and identify *each term* of your mass balance equation with reference to the diagram.



   (b) (10 points) What is the concentration C of the pollutant in the lake, expressed in mg/L?

   0.5 mg/L

Problem 1, continued.

(d) (5 points) Consider a situation in which the pollutant discharge into the lake is eliminated. (That is, the only flow into the lake is the clean stream.) Write the mass balance equation for the mass of pollutant in the lake shortly after the time the discharge is eliminated. **Use symbols (Q, C, V, etc.) rather than numerical values in your equation.**

$$V \frac{dC}{dt} = \emptyset - QC$$

(e) (5 points) Write the equation for concentration in the lake as a function of time after the discharge is eliminated. Circle your final equation, which should be in the form $C(t) = \ldots$
Use symbols (Q, C, V, etc.) rather than numerical values in your equation.

$$C(t) = C(0)\, e^{-\frac{Q}{V} t}$$

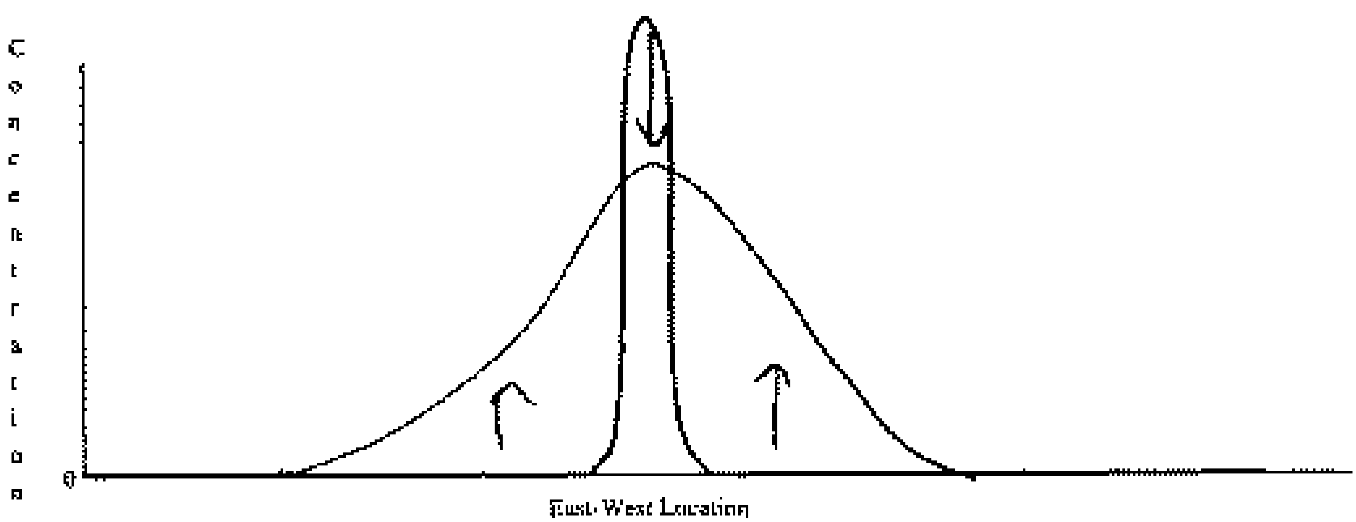
(f) (5 points) For the situation in part (d,e), what is the pollutant concentration in the lake 3 days after the discharge is eliminated?
If you did not obtain an answer for part (b), assume that the concentration at $t = 0$ is 100.0 mg/L.

2. (5 points) What is the retention time of the pond in problem 1(a)? **Express your answer in units of days.**

1.93 days

3. A drop of dye has been dropped into the center of an otherwise clear lake. The concentration of dye as a function of East-West distance across the lake shortly afterwards is shown in the figure below.

   (a) (10 points) What would the plot of concentration versus E-W location look like some time later? Draw the expected profile on the plot below. Assume that the lake is infinitely large and that there is no current in the lake.



   (b) (5 points) Most of the transport of dye in this problem would occur through (circle the best answer):

mechanical dispersion **advection**

molecular diffusion **turbulent diffusion**

6. A particle is settling through water at its terminal velocity.

   (a) What is/are the downward force(s) acting on the particle?

   - (5 points) Identify each force by name or by description.

   - (5 points) Provide a formula for one of the <u>force</u>(s), in terms of particle diameter (D_p), particle density ρ_p, particle settling velocity (v_p), fluid density (ρ_f), and/or any other needed parameters (don't use numerical values for these parameters).

   (b) What is/are the upward forces acting on the particle?

   - (5 points) Identify each force by name or by description.

   - (5 points) Provide a formula for one of the <u>force</u>(s), in terms of particle diameter (D_p), particle density ρ_p, particle settling velocity (v_p), fluid density (ρ_f), and/or any other needed parameters (don't use numerical values for these parameters).

Equations and Constants

Density of water = 1.00 g/cm^3
Viscosity of water = 0.01186 g cm^{-1}s^{-1}
Viscosity of air = 1.695×10^{-4} g cm^{-1}s^{-1}
Gas Constant $R = 0.08205\ (L \cdot atm)/(mole \cdot^\circ K)$
$= 8.205 \times 10^{-5}\ (m^3 \cdot atm)/(mole \cdot^\circ K)$
$= 82.05\ (cm^3 \cdot atm)/(mole \cdot^\circ K)$
$= 8.314\ J/(mole \cdot^\circ K)$
Molecular weight of formaldehyde = 30
Heat capacity of water $C_{H_2O} = 4184\ J/(kg \cdot^\circ C)$
$PV = nRT$
$g = 980\ cm/s^2$
$1\ W = 1\ J/s$
10^3 L = 1 m^3
Atomic weights:
C = 12
N = 14
O = 16
S = 32
Fe = 55.8
H = 1
Cl = 35

$$\text{Stokes Settling Velocity: } v_s = \frac{g(\rho_p - \rho_f)}{18\mu} D_p^2$$

$$\text{Stokes Drag Force: } F_D = 3\pi\mu D_p v_s$$

$$J = -D\frac{dC}{dx}$$

$$v_d = Q/A = K\frac{dh}{dx}$$

$$\text{Volume of sphere with diameter } D_p = \frac{\pi}{6} D_p^3$$