DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
UNIVERSITY OF CALIFORNIA, BERKELEY
CE 111 FALL 2016

MIDTERM TWO

Name: SOLUTIONS

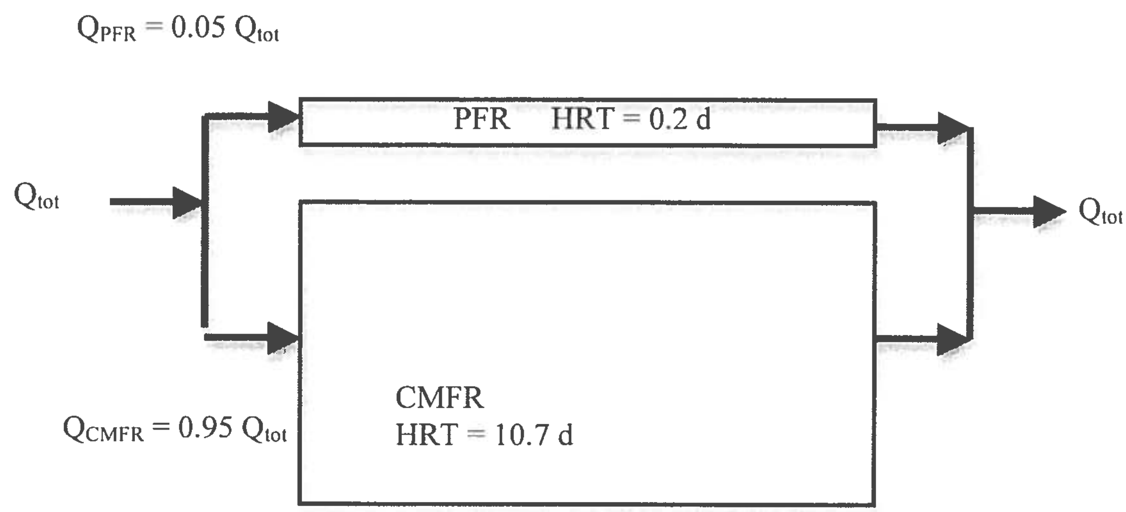
The exam is worth 100 points and has four problems. Make sure to read each question carefully, and allocate your time wisely. You must show all steps of any calculations you perform. Put a box around each final answer. Use the paper provided. You may use the backside of the paper if you need more room. Make sure your name is written on the top of each sheet.

Problem	Score
1	/30
2	/25
3	/25
4	/20
Total	

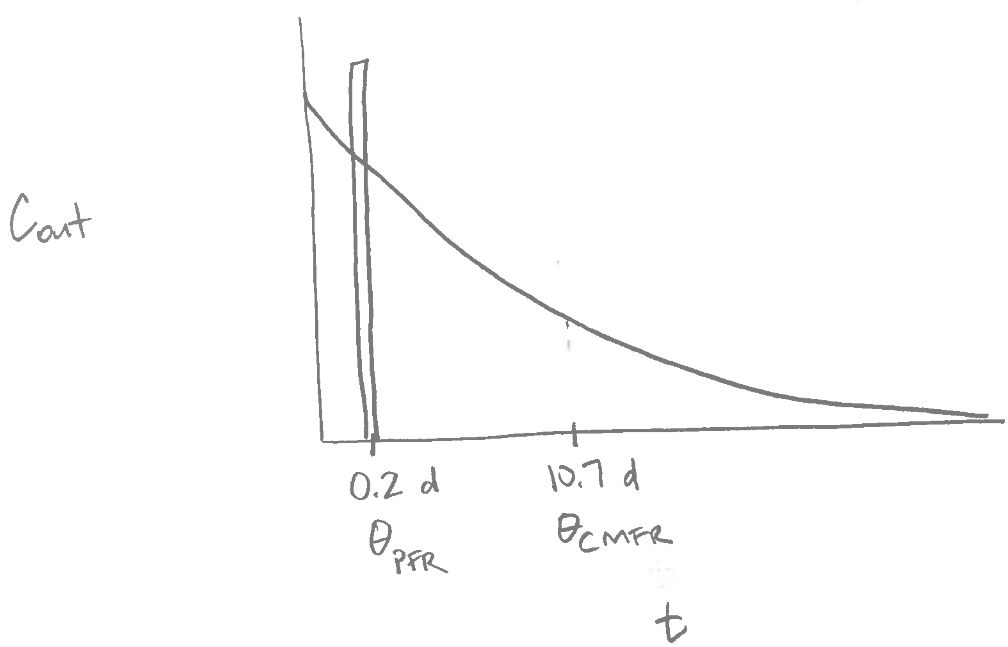
Other rules/expectations:

- The seats are very close together, but **you MAY NOT look at your neighbors' exams**. I will be monitoring the classroom for wandering eyes.
- The only materials you may use are pencil, eraser, and calculator.
- Please fill the seats at the end of each row first, otherwise students that arrive later will have to interrupt an entire row to get to a seat.
- The exams will be passed out when you arrive to class, but you may not look at them.
- Everyone will start working on the exam promptly at 11:10.
- You can tear off the top sheet, which has constants and equations. You do not need to hand this sheet in at the end.
- You will not be allowed to ask any questions during the exam, because it is not possible for students to get out of their seats without disrupting their neighbors. If you feel you do not understand part of a question, re-read it carefully several times. If you still don't understand, make an assumption that allows you to continue and write a short note explaining what your assumption is.
- The exam will end promptly at 12:00. When I announce that the exam has ended, **everyone must put down their pencils immediately.** It is not fair if some students stop and others don't. You will hand your exam to the person at the end of your row, and then I will come and pick them up from each row.

1. (30 points) A reactor system consists of an ideal PFR and an ideal CMFR operating in parallel, as shown in the diagram below (this design can be used to simulate a non-ideal CMFR that has short-circuiting). The CMFR receives 95% of the total flow ($Q_{CMFR} = 0.95\ Q_{tot}$) and the PFR receives 5% of the total flow ($Q_{PFR} = 0.05\ Q_{tot}$).



a. A pulse of non-reactive tracer is added to the inlet at t=0. Draw a graph of the tracer concentration at the outlet (C_{out}) vs. time. Label the location of θ_{PFR} and θ_{CMFR} on the x axis.



b. Now imagine that the reactor system is used to treat a contaminant that undergoes 1st order decay with C_{in} = 250 mg/L and k_1 = 0.5 d^{-1}. Calculate the steady-state effluent concentration, C_{out}, of the contaminant leaving this reactor system. Remember units, and round your answer to 3 significant figures.

$$C_{out} = 0.95\, C_{out,CMFR} + 0.05\, C_{out,PFR}$$

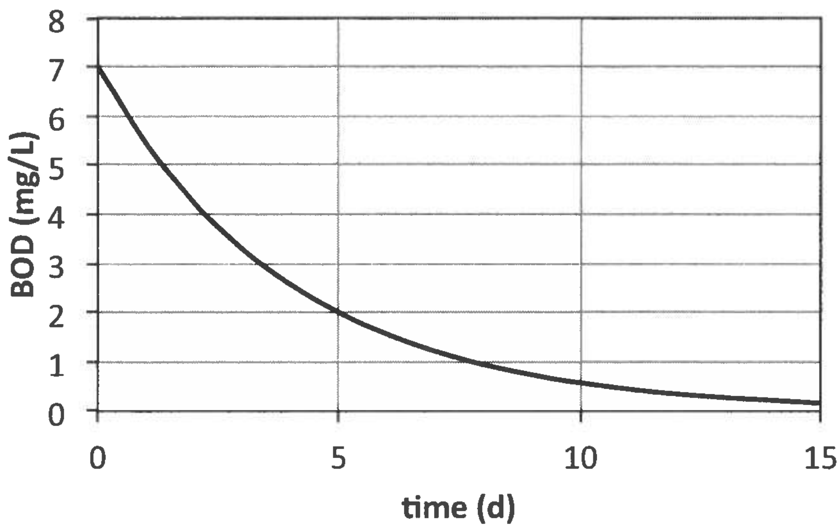
$$C_{out,CMFR} = \frac{C_{in}}{1 + k_1 \theta_{CMFR}} = \frac{250 \text{ mg/L}}{1 + (0.5/d)(10.7d)} = 39.37 \text{ mg/L}$$

$$C_{out,PFR} = C_{in}\, e^{-k_1 \theta_{PFR}} = (250 \text{ mg/L})\, e^{-(0.5/d)(0.2d)} = 226.2 \text{ mg/L}$$

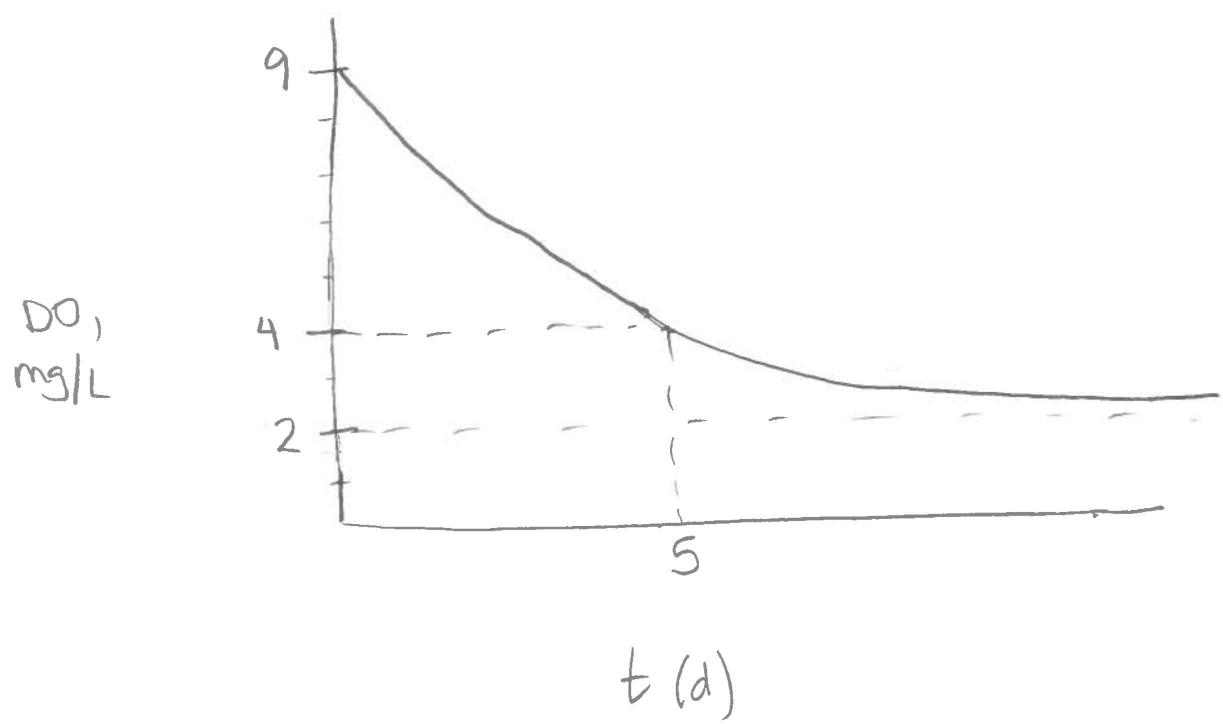
$$C_{out} = (0.95)(39.37) + (0.05)(226.2) = 48.71$$

$$\boxed{C_{out} = 48.7 \text{ mg/L}}$$

2. (25 points) A wastewater sample is tested in the laboratory and in the test bottle, the BOD decreases as shown in the graph below.



a. Draw a graph showing how the DO concentration changes in the BOD bottle as a function of time. Assume that the initial DO concentration in the bottle is 9 mg/L. Label the DO concentration at t = 0, t = 5 d, and t = ∞.



b. If this test was performed on a 1:3 dilution of the original sample, what is the BOD_5 for the original sample? (BOD_5 is the BOD that is exerted in 5 days). Remember units, and round your answer to ~~3~~ 2 significant figures.

BOD_5 in bottle = 7−2 = 5 mg/L

BOD_5 in sample = 3(5) = **15 mg/L**

c. What is k_{BOD} for this sample? Remember units, and round your answer to ~~3~~ 2 significant figures.

$$BOD(t) = BOD_u e^{-k_{BOD} t}$$

Plug in for any value of BOD(t) and t from the chart. Solve for k_{BOD}.

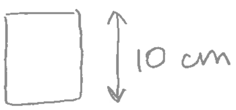
$$\ln\left(\frac{BOD(t)}{BOD_u}\right) = -k_{BOD} t$$

$$k_{BOD} = -\frac{1}{t} \ln \frac{BOD(t)}{BOD_u}$$

$$= -\frac{1}{5d} \ln\left(\frac{2 \text{ mg/L}}{7 \text{ mg/L}}\right)$$

$$\boxed{k_{BOD} = 0.25 \, d^{-1}}$$

3. (25 points) A sample of groundwater contaminated with phenol is collected in a beaker and stored, without any cover or lid, in a laboratory. The depth of water in the beaker is 10 cm.
   a. How much will the concentration of phenol be reduced after one week, due to volatilization (gas transfer), if the overall gas transfer coefficient (k_{gl}) has a value of 10^{-2} cm/h? You can assume that no other processes affect the concentration of phenol. Also assume that phenol does not accumulate in the air to any significant extent, because the laboratory room is vented. Provide your answer as a percentage with three 3 significant figures.



$$\frac{dc}{dt} V = JA = k_{gl}(C_s - c)A$$

$$\frac{dc}{dt} = k_{gl}(C_s - c)\frac{A}{V} = \frac{k_{gl}}{Z}(C_s - c)$$

Note that $C_s = 0$, b/c phenol does not accumulate in the air

$$\frac{dc}{dt} = -\frac{k_{gl}}{z} c$$

$$\int_{C(0)}^{C(t)} \frac{dc}{c} = -\frac{k_{gl}}{z} \int_0^t dt$$

$$\ln \frac{C(t)}{C(0)} = -\frac{k_{gl} t}{Z}$$

$$\frac{C(t)}{C(0)} = e^{-k_{gl}t/z} = \exp -\left(\frac{(0.01 \text{ cm/h})(7\text{d})(24 \text{ h/d})}{10 \text{ cm}}\right)$$

$$= 0.8454$$

% reduction $= (1 - 0.8454)100 =$ **15.5 %**

b. Would you expect the concentration to decrease more quickly if the beaker is stored in a fume hood, in which there is a strong air current (i.e., there is more mixing of the air compared to the room in part a)? Explain your answer briefly. Is there any additional information you would want to have to better answer this question? If so, state it briefly.

It depends on whether gas transfer is limited by diffusion across the stagnant boundary layer on the liquid side, or gas side. If it is limited by the gas side (highly soluble compounds), then <u>YES</u>. If it is limited by the liquid side, then we would expect <u>no change</u>.

So we need to know $\underline{K_H}$, to be able to calculate $\frac{1}{k_\ell}$ and $\frac{K_H RT}{k_g}$ to determine which side dominates the resistance.

4. (20 points) Answer the following questions with brief written response.
   a. Membranes can be used to remove impurities from water. Explain the dominant removal mechanism of impurities by microfiltration compared to reverse osmosis.

Microfiltration: straining - the particles cannot pass through the pores of the membrane

RO: Dense membrane, no pores. Removal occurs because water diffuses through the membrane at a faster rate than impurities (permeability of water > permeability of impurity)

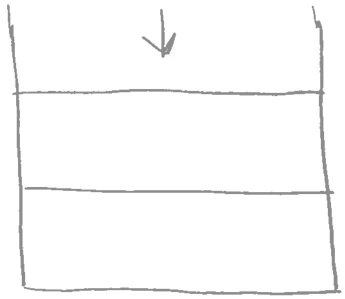
   b. Reverse osmosis (RO) is an attractive technology for addressing water scarcity because it can be used for desalination of seawater or brackish water. However, there are several reasons why RO has not yet experienced widespread adoption. List three drawbacks of RO.

best answers

1. Expensive
2. Energy intensive
3. Creates a concentrated brine stream that must be disposed of.

Also discussed tears in membrane or leaks in the seals being a problem; this is more a concern for pathogens than for salt.

c. It is common to use two different types of media for rapid granular media filtration. Explain why.



← larger diameter media: lower head loss, but still removes particles

← smaller diameter media: higher head loss but better particle removal

Using two media types is a strategy to maximize particle removal while minimizing head loss

d. Nitrogen is typically the limiting nutrient in estuaries, whereas phosphorus is typically the limiting nutrient in lakes. Explain briefly why it is important to control the concentration of limiting nutrients.

To prevent eutrophication. The limiting nutrient controls how much growth of algae will occur. ~~If~~ If algae grow, they settle to bottom when they die, and become BOD. When the dead algae are degraded, oxygen depletion can occur.