ENV 4001: ENVIRONMENTAL SYSTEMS ENGINEERING

Fall 2020	University of South Florida
Test #1	Civil & Environmental Eng.
Wednesday, February 17	Prof. J.A. Cunningham

Instructions:

1. Sign in to Canvas and launch Test #1. It should be available under the Quizzes tab and/or the Assignments tab. Test #1 in Canvas doesn't contain very much information, but it does include places to submit your numerical answers. The actual test questions are in this document on the pages that follow.
2. This test contains three questions. Answer all three.
3. Questions have multiple parts. The point value of each part is indicated. The total number of points possible is 60.
4. Unit conversion factors and other potentially useful information are provided on the following page.
5. Answer each question on your own paper. Put your name on each page of paper.
6. Show your work and state any important assumptions you make. I cannot award partial credit if I can't follow what you did.
7. Report a reasonable number of significant digits in your answers. Sometimes a question might specify the number of significant digits to report.
8. Include units in your answers as appropriate. An answer without proper units is not correct!
9. You are allowed to use your text book, your course notes, or any other printed materials. However, *you may not receive help from another live person*.
10. A hand-held calculator is recommended.
11. **Numerical answers should be uploaded and submitted in Canvas by 12:15 PM**. The test will close in Canvas at 12:15 PM.
12. *After* submitting your answers in Canvas, scan your work and send it to me by e-mail (cunning@usf.edu). E-mail me your file before 12:25 PM. Answers in your scanned work must match the numerical answers that you uploaded to Canvas.
13. **Don't cheat**. Cheating will result in appropriate disciplinary action according to university policy. More importantly, cheating indicates a lack of personal integrity.
14. Hints:
    - Read each question carefully and answer the question that is asked.
    - Watch your units. If you take good care of your units, they will take good care of you.
    - Work carefully and don't rush.

Potentially useful constants:

Ideal gas constant, R:	8.314 $Pa \bullet m^3 \bullet mol^{-1} \bullet K^{-1}$ = 82.06×10^{-6} $atm \bullet m^3 \bullet mol^{-1} \bullet K^{-1}$
Gravitational acceleration, g:	9.81 m/s^2
Molecular weight of water, H_2O:	18.01 g/mole
Density of water at 25 °C:	0.9970 g/mL = 997 kg/m^3
Viscosity of water at 25 °C:	0.890×10^{-3} Pa•sec
Density of air at 25 °C:	1.18 kg/m^3
Viscosity of air at 25 °C:	1.85×10^{-5} Pa•sec

Potentially useful conversion factors:

Pressure:	1 atm = 760 mm Hg = 760 torr = 101325 Pa
	1 Pa = 1 N/m^2 = 1 $kg/(m \bullet sec^2)$
Mass:	1 kg = 1000 g = 10^6 mg = 10^9 μg
	1 kg = 2.207 lb_{mass}
	1 t (metric tonne) = 1000 kg = 2207 lb_{mass}
	1 ton (English ton) = 2000 lb_{mass}
Length:	1 km = 1000 m = 10^5 cm = 10^6 mm = 10^9 μm
	1 ft = 12 in = 30.48 cm = 0.3048 m
Temperature:	25 °C = 298.15 K
Volume:	1 m^3 = 1000 L = 10^6 mL = 10^6 cm^3
	1 gal = 3.785 L
Work/Energy:	1 BTU = 1.055 kJ
Power:	1 MW = 10^6 W = 10^6 J/s = 10^6 N•m/s
Area :	1 ha = 10^4 m^2

Atomic Masses:

H = 1.008 g/mole	C = 12.011 g/mole	N = 14.007 g/mole	O = 15.999 g/mole
P = 30.974 g/mole	S = 32.06 g/mole	Cl = 35.453 g/mole	Br = 79.904 g/mole
Na = 22.99 g/mole	Mg = 24.31 g/mole	Al = 26.98 g/mole	K = 39.10 g/mole
Ca = 40.08 g/mole	Fe = 55.85 g/mole	Cu = 63.55 g/mole	

1. (16 pts) (111) In the treatment of drinking water, which we will study later this semester, sometimes we add $Al_2(SO_4)_3$ (aluminum sulfate, also called "alum") to the water. When the alum dissolves in the water, it releases Al^{3+} ions into the water. The Al^{3+} then forms small particles, called "flocs", of solid $Al(OH)_3$ precipitate. The $Al(OH)_3$ flocs are useful in the water-treatment process for reasons we will study later.

    That is a pretty good system, but there is one potential problem. It is best if the concentration of Al^{3+} in the water does not exceed about 0.1 mg/L, which is pretty low. This concentration is a "secondary standard" for aluminum, which means it is a recommended upper limit, but it's just a recommendation, not a strict legal limit. Let's find out if the addition of alum will violate the secondary standard.

    a. (12 pt) Suppose the pH of the water being treated is 5.8. Estimate/calculate the concentration of Al^{3+} in the water, in units of mg/L, assuming that the system is at equilibrium. Hint: there is Al^{3+} in the water, and also there are $Al(OH)_3$ flocs in the water, and the system is at equilibrium.

    b. (4 pt) Based on your answer to part (a), do you think meeting the secondary standard for aluminum is a problem for drinking-water treatment plants that use alum during their treatment? Explain very briefly – only a sentence or two is needed.

2. (28 pts) (111) Suppose a water stream contains a hazardous chemical called Chemical X. The bad news is that Chemical X is very toxic. The good news is that Chemical X can be pretty easily converted to Chemical Y, which is non-toxic. You want to design a reactor to remove Chemical X from the water.

   To figure out how to design your reactor, first you ran a batch reactor test to figure out how fast Chemical X is converted to Chemical Y. Here are the results of your batch reactor test.

time (min)	conc. of Chemical X (mmol/L)
5	1.6
10	0.80
15	0.40
20	0.20
25	0.10

   a. (8 pts) Based on the data, what reaction order is the conversion of Chemical X? Show your calculations and/or explain your reasoning, as necessary.

   b. (8 pts) Estimate/calculate the reaction rate coefficient for the conversion of Chemical X. Be sure to specify the correct units for the reaction rate coefficient.

   Now that you know how fast Chemical X reacts, you can design a reactor to treat the contaminated water. The flow rate of the contaminated water is 25 m^3/hr. The concentration of Chemical X in the water is 1.0 mmol/L, and you want to reduce it to no greater than 0.05 mmol/L.

   c. (4 pts) Which do you recommend for the job, a completely mixed flow reactor or a plug flow reactor? Why? Explain briefly.

   d. (8 pts) For whichever type of reactor you specified in part (c), specify the volume of reactor that will be required to achieve the desired conversion. Report your answer in units of m^3.

3. (16 pts) (111) A student collected a water sample from a river that is known to be slightly polluted. The student took his water sample to the lab and monitored the concentration of dissolved oxygen in the water over time. The concentration of dissolved oxygen decreased because a contaminant in the river exerts some biochemical oxygen demand (BOD). Unfortunately, the student forgot to write down the time at which he took a couple of his measurements! Here are the data that the student wrote down:

Sample #	Time measured (d)	O_2 concentration (mg/L)
1	0	8.90
2		4.0
3		2.5
4	8	2.1
5	9	2.1
6	10	2.10

a. (6 pts) Estimate/calculate the initial concentration of the contamination in the river, *expressed as oxygen demand*. Report your answer in units of mg/L.
Hint #1: What is the relationship between BOD_{ult} and L_0? – one of these is pretty easy to find from the data given above.
Hint #2: You don't need a lot of complicated calculations to do this part of the problem.

Luckily, we know that the rate coefficient for the first-order decay of the contaminant in the river. It is $k_1 = 0.80\ d^{-1}$. Therefore we can infer the measurement times of the samples which the student forgot to label.

b. (6 pts) Estimate/calculate the time (in days) at which sample #2 was analyzed. Report your answer to two significant digits.

c. (4 pts) Estimate/calculate the time (in days) at which sample #3 was analyzed. Report your answer to two significant digits.

END OF TEST