ENV 4001: Environmental Systems Engineering

Spring 2021	University of South Florida
Test #2	Civil & Environmental Eng.
Wednesday, March 24	Prof. J.A. Cunningham

Instructions:

1. Sign in to Canvas and launch Test #2. It should be available under the Quizzes tab and/or the Assignments tab. Test #2 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 may 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*:	$8.314\ Pa\bullet m^3\bullet mol^{-1}\bullet K^{-1} = 82.06\times10^{-6}\ atm\bullet m^3\bullet mol^{-1}\bullet K^{-1}$
Gravitational acceleration, *g*:	$9.81\ m/s^2$
Molar mass of water, H_2O:	18.01 g/mole
Density of water at 20 °C:	$0.9984\ g/mL = 998\ kg/m^3$
Viscosity of water at 20 °C:	1.002×10^{-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:	$1\ kg = 1000\ g = 10^6\ mg = 10^9\ \mu g$
	1 kg = 2.207 lb_{mass}
	1 t (metric tonne) = 1000 kg = 2207 lb_{mass}
	1 ton (English ton) = 2000 lb_{mass}
Length:	$1\ km = 1000\ m = 10^5\ cm = 10^6\ mm = 10^9\ \mu m$
	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:	$1\ MW = 10^6\ W = 10^6\ J/s = 10^6\ N\bullet m/s$
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	Ca = 40.08 g/mole	Fe = 55.85 g/mole

Equilibrium Concentrations of Oxygen (O_2) in Fresh Water (air/water equilibrium):

Temperature (°C)	Equil. Conc. of O_2 (mg/L)	Temperature (°C)	Equil. Conc. of O_2 (mg/L)
15	10.15	21	8.99
16	9.95	22	8.83
17	9.74	23	8.68
18	9.54	24	8.53
19	9.65	25	8.38
20	9.17	26	8.22

TABLE 6–4 Slope Factors for Potential Carcinogens[a]

Chemical	CPS_0 ($kg \cdot day \cdot mg^{-1}$)	CPS_i ($kg \cdot day \cdot mg^{-1}$)
Arsenic	1.5	15.1
Benzene	0.015	0.029
Benzo(*a*)pyrene	7.3	N/A
Cadmium	N/A	6.3
Carbon tetrachloride	0.13	0.0525
Chloroform	0.0061	0.08
Chromium (VI)	N/A	42.0
DDT	0.34	0.34
1,1-Dichloroethylene	0.6	0.175
Dieldrin	16.0	16.1
Heptachlor	4.5	4.55
Hexachloroethane	0.014	0.014
Methylene chloride	0.0075	0.00164
Polychlorinated biphenyls	0.04	N/A
2,3,7,8-TCDD[b]	1.5×10^5	1.16×10^5
Tetrachloroethylene[b]	0.052	0.002
Trichloroethylene[c]	w	0.006
Vinyl chloride[b]	1.9	N/A

CPS_0 = cancer potency slope, oral; CPS_i = cancer potency slope, inhalation; w = withdrawn from IRIS.

[a] Values are frequently updated. Refer to IRIS and HEAST for current data.

[b] *Annual Health Effects Assessment Summary Tables* (HEAST) U.S. Environmental Protection Agency, 540/R-94/036, 1994.

[c] U.S. Environmental Protection Agency, National Center for Environmental Assessment http://www.epa.gov/ncea

Source: With the exceptions noted this information is taken from the U.S. Environmental Protection Agency, IRIS database, September 2005.

TABLE 6–5 RfDs for Chronic Noncarcinogenic Effects for Selected Chemicals[a]

Chemical	Oral RfD ($mg \cdot kg^{-1} \cdot day^{-1}$)	Chemical	Oral RfD ($mg \cdot kg^{-1} \cdot day^{-1}$)
Acetone	0.9	Phenol	0.3
Barium	0.2	PCB	
Cadmium	0.0005	Aroclor 1016	7.0×10^{-5}
Chloroform	0.01	Aroclor 1254	2.0×10^{-5}
Cyanide	0.02	Silver	0.003
1,1-Dichloroethylene	0.05	Tetrachloroethylene	0.01
Hydrogen cyanide	0.02	Toluene	0.2
Methylene chloride	0.06	1,2,4-Trichlorobenzene	0.01
Pentachlorophenol	0.03	Xylenes	0.2

[a] Values are frequently updated. Refer to IRIS for current data.

Source: U.S. Environmental Protection Agency IRIS database, 2005.

from "Principles of Environmental Engineering and Science", 2nd edition, by Davis and Masten

1. (15 pts) (111) We have discovered that the drinking water in the city of Malasuerte is contaminated with a hazardous chemical called toxicane. It seems that the chemical has been in the water supply ever since the 1940s, as a result of an experimental program conducted nearby during World War II. Ever since then, the concentration of toxicane in the water supply has been around 100 μg/L. Now we are trying to figure out if the presence of toxicane in the water supply has led to any health consequences for the residents of Malasuerte.

   During the "Baby Boom" of 1946–1955, about 36,000 babies were born in Malasuerte. Of these 36,000 people, 30 of them developed a rare form of esophageal cancer at some point in their lives. We think maybe it is because of the toxicane in the water.

   The nearby town of Buenafortuna is about the same size as Malasuerte, and also had about 36,000 babies born between 1946–1955. However, in Buenafortuna, only 6 of these 36,000 "boomers" developed the rare esophageal cancer.

   a. (5 pts) Estimate/calculate the incremental lifetime risk of contracting esophageal cancer due to the presence of toxicane in the water. Report your answer to two significant digits. For the purposes of this problem, you may assume that the only significant difference between living conditions in Malasuerte and living conditions in Buenafortuna is the presence (or absence) of toxicane in the drinking water.

   b. (10 pts) Estimate/calculate the cancer slope factor for oral ingestion of toxicane. Report your answer to two significant digits, using units of $(\text{mg/kg}\bullet\text{d})^{-1}$. For the purposes of this exam, you may assume the following: (i) the people born in Malasuerte lived in that city for an average of 40 years throughout their lives; (ii) a person's average body mass is 70 kg.

   Be sure to show all your work and state any important assumptions that you make. Report your numerical answers in the appropriate places in Canvas.

2. (20 pts) (111) Recently, the residents in the vicinity of Jensen River realized that there is a "dead spot" in the river that seems to be devoid of fish. The "dead spot" extends from about 24 km to about 26 km downstream of a factory that discharges its wastewater into the river. The residents surmised that the factory is the cause of the dead spot, so they collected some water samples from just a little bit downstream of where the factory discharge enters the river. Here is what they determined from the water samples that they collected.

- The temperature of the river is 22 °C.
- The concentration of dissolved oxygen in the collected water samples was 7.00 mg/L.
- The biochemical oxygen demand in the collected water samples (BOD_{ult}) was 20.0 mg/L.
- The rate coefficient for biodegradation of organic contaminants in the river is 0.20 d^{-1}.
- The rate coefficient for reaeration of the river by the atmosphere is 0.45 d^{-1}.

There are a couple things that, for some reason, nobody bothered to measure. One is the average velocity of the river. Another is the concentration of dissolved oxygen in the "dead spot" of the river. It won't be too difficult to send somebody back out to the river to take these measurements, but before we do that, let's calculate what values we think we should get.

a. (12 pts) Estimate/calculate the average velocity of the river, in units of km/d. Hint: you know the location of the dead spot in the river.

b. (8 pts) Estimate/calculate the concentration of dissolved oxygen that you would expect to measure in the dead spot of the river.

Report your answers in the appropriate places in Canvas.

3. (25 pts) (111) Your engineering firm has been hired to design a new drinking-water treatment plant to treat water taken from the Jensen River. (…a different stretch of river from that considered in problem 2.) The river water will be filtered via granular media filtration. Although you probably would use dual-media filtration in real life, for the purposes of this problem, we will assume that you are using a single filter medium: sand. Here is some information about the filtration process.

- Design flow rate to be treated is 3.1×10^6 L/hr (equivalent to nearly 20 million gallons per day).
- You are going to design a number of filters to be operated in parallel; this is standard design practice. That way, when one filter is being backwashed, all the other filters can still be in operation. Each filter will have a cross-sectional area of 25 m^2 (5.0 m by 5.0 m square).
- Each filter will be comprised of a layer of sand grains that is 0.80 m deep.
- The sand grains have a diameter of 0.4 mm, a density of 2650 kg/m^3, and an initial (clean-filter) porosity of 0.42.
- The water temperature is 20 °C.

Your job is to *determine how many filters must operate in parallel to ensure that the initial head loss* (i.e., the clean-filter head loss) *is less than 1.0 m*. Show your work and clearly state any assumptions. Report your answer in Canvas.

YOU MUST SHOW YOUR WORK TO EARN CREDIT FOR THE PROBLEM. YOU WILL GET VERY LITTLE PARTIAL CREDIT FOR A LUCKY GUESS.

Hint #1: You will make your life easier if you convert all parameters into a consistent system of units (e.g., meters, kilograms, seconds).

Hint #2: How is head loss related to "filter velocity", and how is "filter velocity" related to the number of filters in operation? If you increase the number of filters in operation, what happens to the filter velocity in each filter, and then what happens to the head loss in each filter?

Hint #3: Depending on your approach, you might have to solve a quadratic.

END OF TEST