ENV 4001: ENVIRONMENTAL SYSTEMS ENGINEERING

Fall 2021 University of South Florida
Test #2 Civil & Environmental Eng.
Monday, November 1 Prof. J.A. Cunningham

SPECIAL HALLOWEEN EDITION

Instructions:

1. You may read these instructions, but do not turn the page or begin working until instructed.
2. This test contains four questions. Answer question 1. Then, answer ***any two of the final three questions***.
3. If you attempt *all* the problems (not recommended), make sure you clearly indicate which ones you want me to grade. If it is not clear, I will grade whichever ones I think I can grade the fastest. That might not work in your favor.
4. Some questions might have multiple parts. In those cases, the point value of each part is indicated. The total number of points possible is 60.
5. Unit conversion factors and other potentially useful information are provided on the back of this page, and on the page after that.
6. Answer each question in the space provided. If you need more space, you can attach additional pages as needed, but make sure to put your name on them.
7. Show your work and state any important assumptions you make. I cannot award partial credit if I can't follow what you did.
8. Report a reasonable number of significant digits in your answers. In some cases, the problem might specify how many significant digits to report.
9. Include units in your answers. An answer without proper units is not correct!
10. You are allowed to use your text book, your course notes, or other printed materials. You may not receive help from another person.
11. A hand-held calculator is recommended. Other electronic devices are not permitted.
12. Time limit: 60 minutes. Stop working when asked. If you continue working after time has been called, you will be penalized at a rate of 1 point per minute.
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. Please print your name legibly in the space provided below, and turn in this test at the end of the period.
15. 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.

Name: _____

Potentially useful constants:

Ideal gas constant, *R*:	$8.314\ Pa \cdot m^3 \cdot mol^{-1} \cdot K^{-1} = 82.06 \times 10^{-6}\ atm \cdot m^3 \cdot mol^{-1} \cdot K^{-1}$
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:	$0.890 \times 10^{-3}\ Pa \cdot sec$
Density of air at 25 °C:	$1.18\ kg/m^3$
Viscosity of air at 25 °C:	$1.85 \times 10^{-5}\ Pa \cdot sec$

Potentially useful conversion factors:

Pressure:	1 atm = 760 mm Hg = 760 torr = 101325 Pa
	$1\ Pa = 1\ N/m^2 = 1\ kg/(m \cdot sec^2)$
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:	$1\ MW = 10^6\ W = 10^6\ J/s = 10^6\ N \cdot m/s$
Area :	$1\ ha = 10^4\ m^2$

Atomic Masses for a few selected elements:

H = 1.008 g/mole	C = 12.011 g/mole	N = 14.007 g/mole	O = 15.999 g/mole
Na = 22.99 g/mole	Mg = 24.31 g/mole	P = 30.974 g/mole	S = 32.06 g/mole
Cl = 35.453 g/mole	Ca = 40.08 g/mole	Fe = 55.85 g/mole	Br = 79.904 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 · day · mg^{-1})	CPS_i (kg · day · 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 · kg^{-1} · day^{-1})	Chemical	Oral RfD (mg · kg^{-1} · 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

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1. (10 pts) Below, I have listed six *targets* for the UN Sustainable Development Goals (SDGs). For each target listed, give the *number*, the *name*, and the *brief description* of the SDG that goes with the target. As an example, I filled in the first one for you.

Target	**SDG number**	**SDG name**	**SDG brief description**
By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty	1	No poverty	End poverty in all its forms everywhere
By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy			
Integrate climate change measures into national policies, strategies and planning			
By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency			
By 2030, improve water quality by reducing pollution, eliminating dumping, and minimizing release of hazardous chemicals			
By 2030, provide access to safe, affordable, accessible, and sustainable transport systems for all			

2. (25 pts) *particle flocculation* Three witches were gathered around their cauldron, making their traditional witches' brew. They added eye of newt, toe of frog, owlet's wing – all the traditional ingredients. As they gently stirred the cauldron, one of the witches noticed something interesting: when one eye of newt collided with another in the brew, the eyes would sometimes stick together and form a clump. This witch was worried that the brew would be spoiled if all the eyes-of-newt stick together. (Witches hate clumpy brew.)

   a. (8 pts) The cauldron holds 300 L of witches' brew, and the witches initially added 600 eyes of newt to the brew. Each eye can be considered as perfectly spherical, with a diameter of 1.0 mm. Based on this, estimate Ω, the volume fraction of the eyes in the brew. In other words, of the 300 L of brew, what fraction is occupied by eyes of newt?

   b. (3 pts) Which of the three ideal reactor types is the best description of the witches' cauldron? Why?

As the witches stir, the *number* of eyes in the brew will reduce – when two eyes collide and stick together, we go from two small eyes to one larger clump. For the purposes of this problem, we will consider that a clump of newt-eyes is also an "eye". That is, we don't distinguish between a single eye of newt and a clump of more than one eye. The witches stir the cauldron gently, so let's estimate that the velocity gradient in the cauldron is $G = 20\ s^{-1}$. For a worst-case scenario, let's also assume that when two eyes of newt collide with each other, they stick together with perfect efficiency: $\alpha = 1$.

problem 2 continues →

2. continued

c. (11 pts) Assume the witches stir the brew for 30 minutes. *Estimate/calculate how many eyes of newt you expect to find remaining in the witches' brew after they stir for 30 minutes*. Hint: the rate of eyeball flocculation is given by $R = (4/\pi)\ \alpha\ G\ \Omega\ N$, where N is the number concentration of eyes (or clumps of eyes, which we're treating as the same thing). So you know what kind of reactor it is (from part b), and you know how the rate depends on the concentration….

d. (3 pts) Does the witch need to worry about the brew being spoiled by flocculation of the eyes-of-newt? Explain very briefly (one sentence).

e. EXTRA CREDIT. In what play do the witches brew a concoction with eye of newt and toe of frog? +1 for naming the play, +1 for naming the act and scene in which it occurs, and +1 for naming any of the other ingredients that I didn't already list in this problem.

3. (25 pts) Two demons in the Land of the Dead were comparing notes on the horrible, atrocious things they did while they were alive.

   The first one said "When I was alive, I had a co-worker whom I hated. She was a little thing, but she sure was mean to me. I noticed that she drank a big mug of coffee every day, so I started putting arsenic in it. When she wasn't looking, I'd put 1 mg of arsenic into her mug. I did it every work day for 5 years before I got caught and sent to prison."

   The second demon was not impressed. "Hmph. Arsenic in the coffee. How unoriginal. When *I* was alive, I couldn't stand my husband. He was a very large man and he snored terribly. It got so bad that I had to sleep in a separate wing of our mansion. So I started pumping chloroform gas into his bedroom while he was sleeping. I could get the concentration of chloroform up to about 10 mg/m^3 while he was getting his eight hours of sleep. I did it every night for 10 years before I got caught and sent to prison."

   Which of these vile, despicable demons created a higher risk of contracting cancer for his/her victim? Show your calculations to support your answer. You must show your work to get credit!

problem 3 continues →

3. continued
additional space for your answer

4. (25 pts) Trixie Treete operates Trixie's Trout Farm along the Ygor River. She grows her trout in cages that are submerged in the river. Trixie and her trout are happy because the Ygor River is pretty clean. Unfortunately for Trixie and her business, the Sickly Sweet Candy Company is thinking about building a new candy factory along the river, upstream of her trout farm. The proposed factory would discharge its waste, full of organic compounds (which exert oxygen demand), into the river. Trixie is worried because her trout need at least 6.0 mg/L of dissolved oxygen in the river to stay healthy. They haven't yet decided exactly where they will build the candy factory, but it would be somewhere 15–85 km upstream of Trixie's Trout Farm.

   Here is what we know about the river and the proposed wastewater stream:

   - Currently, the Ygor River flows with a volumetric flow rate of 15 m^3/s, has a concentration of dissolved oxygen equal to 9.2 mg/L, and has a low concentration of dissolved organic carbon -- BOD_5 = 4.0 mg/L.
   - The river and the proposed waste discharge stream both have a temperature of 17 °C.
   - The proposed wastewater stream will enter the river at a rate of 0.5 m^3/s and has a high concentration of dissolved organic carbon -- BOD_3 = 180 mg/L. It contains no dissolved oxygen.
   - Stream hydrologists have estimated that, if the waste is discharged into the river, the river depth will be 2.0 m and the river velocity will be 0.25 m/s.
   - The deoxygenation rate coefficient for both the river and the proposed waste stream is 0.25 d^{-1}. The reaeration rate coefficient for the river, based on the expected depth and velocity, is estimated to be 0.70 d^{-1}.

   Ms Treete has hired you as a technical consultant to help her figure out what legal action she should take about the siting of the proposed factory.

   (a) (15 pts) From your client's point of view, where would be the *worst* place to put the proposed factory? Show the calculations that support your answer.

problem 4 continues →

4. continued
additional space for your answer – write on the back of this page if necessary

b. (10 pts) Assume that the worst-case scenario comes to pass, and they build the factory at exactly the spot that you said would be worst. Are Trixie's trout in trouble, or should she stop worrying? Show the calculations to support your answer to Trixie.

END OF TEST