Exam #2

Please grade the following questions:

1, 2, 3
6, 7, 8

Circle two from each row. You must answer 4, 5, 9 and 10

Closed Book, two sheets of notes allowed
Please answer questions 4, 5, 9 and 10. In addition, answer two questions from 1-3 and two from 6-8. The total potential number of points is 100. Show all work. Be neat, and box-in your answer.

A. Water Quality & Regulations: Answer any 2 of the following 3 questions (5 points each)

1. Standards

State the name and key feature of the two major types of US EPA drinking water standards. Correctly name one contaminant in each category (5 points)

2. Definition 1

What are the meanings of the acronyms "MCL" and "TT" as related to US EPA drinking water standards? What are the key features of these standards? (5 points)

3. Definition 2

Define the term "pathogen", and give two examples. (5 points)

B. Disinfection: Answer both question #4 and question #5 (30 points total)

4. Disinfection Effectiveness (7 points)

Name three of the major factors that impact the effectiveness of chemical disinfection processes used in drinking water treatment. (7 points)

5. Tracer Problem (23 points)

The hydraulics of the disinfection contact tank at a water treatment plant are described by Figure 1 showing continuous (or step) input tracer study results (C_{out}/C_0 vs. time) for a flow of 1.5 MGD at a mean hydraulic detention time of 42 minutes. Some US EPA stipulated requirements for "Ct" values are described in Table 1.

Figure 1. Normalized Tracer Study Results

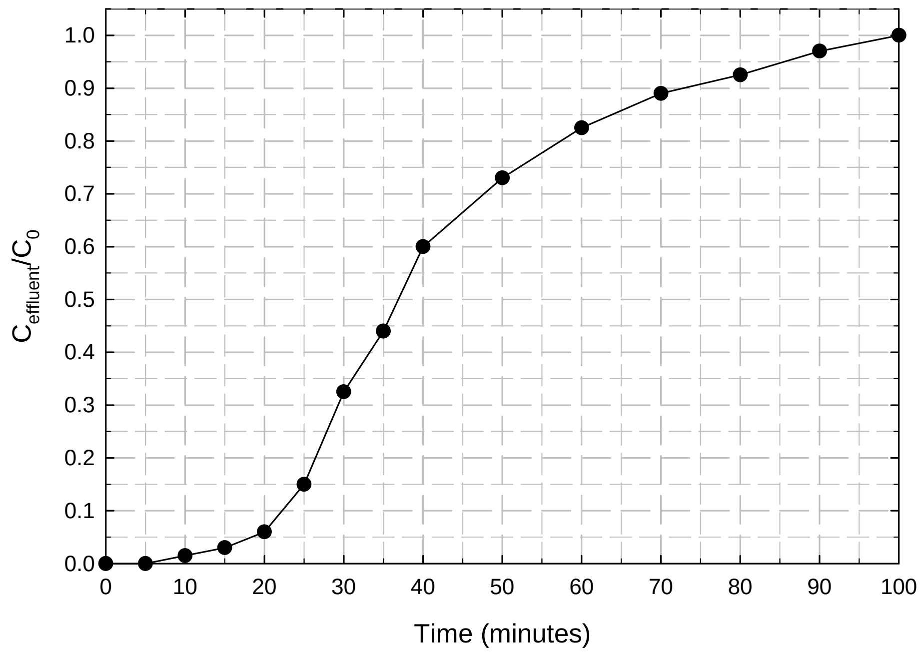

Table 1.

Disinfectant	**Ct values (mg L^{-1} min) for *Giardia* Inactivation, water temp of 5ºC**	
	1 log	**3 log**
Free Chlorine, pH=6.0	35	105
Free Chlorine, pH=8.0	72	216
Chlorine Dioxide	8.7	26
Ozone	0.63	1.9
Chloramine	735	2200

(Ignore any chlorine concentration effects on Ct.)

a) **(7 Pts)** Why are the "Ct" values for free chlorine much higher at pH=8.0 as compared to pH = 6.0? Include chemical species in your explanation (by words or formulas).

b) **(7 Pts)** Suppose the treatment process was disinfection only (no filtration). For the reactor hydraulics shown in Figure 1, what is the minimum allowable ozone residual in the contact tank effluent to achieve 3 log *Giardia* inactivation at a water temperature of 5 ºC?

c) **(4 Pts)** If a clever CEE 371 Engineer put baffles in the contact tank so that it behaved as a plug flow reactor, what would be the minimum allowable tank effluent ozone concentration? Explain your calculation.

d) **(3 Pts)** Would ozone be useful as a secondary disinfectant? Explain your answer.

e) **(2 Pts)** Name two specific treatment processes that can be used to provide a barrier against pathogen contamination of drinking water <u>without</u> the addition of treatment chemicals.

C. <u>Coagulation and Flocculation</u>: Answer any 2 of the following 3 questions (6 points each)

6. Coagulants (6 points)

Name the most common chemical coagulant used in the coagulation process in drinking water treatment, and state the two main objectives of coagulation (i.e., the process of chemical addition and rapid mixing).

7. Power (6 points)

What power input (in kW) is required to achieve a mixing intensity (G) of 750 sec^{-1} in a mechanical rapid mixing tank with a mean hydraulic detention time of 50 seconds at a water flow of 7000 m^3/day? Assume a water temperature of 10 ºC.

8. Flocculation Design (6 points)

Consider the flocculation process used in drinking water treatment:

a. What is the main objective of this treatment process, and what is a typical design value for the mean hydraulic detention time of the process?

b. What are typical design values for the mixing intensity in each stage of a typical three stage tapered flocculation process? Why is this type of flocculation utilized?

D. <u>Settling and Filtration</u>: Answer both question #9 and #10 (48 points total)

9. Settling (30 points)

A single rectangular sedimentation basin is to be designed to treat a water flow of 1.5 MGD at the design overflow rate of 900 gpd/ft^2 .

(10 Pts) Determine the basin dimensions (width, length, depth) for a detention time of 3 hours and a length to width ratio of 4 to 1. (use English units)

(10 Pts) If the sedimentation tank behaves like an ideal plug flow reactor, will all particles with a 65 micron (10^{-6} m) diameter (or greater) and a density of 1200 kg/m^3

be completely removed by the ideal sedimentation tank? (water temperature is 10 ºC) Prove your answer quantitatively.

(5 Pts) If the flow rate to the sedimentation tank increases, resulting in a higher overflow rate, would the particle removal efficiency decrease, stay the same, or increase? Briefly explain.

(5 Pts) Suppose the depth of the sedimentation tank was reduced by 50%, and you could assume discrete particle settling. What is the effect on particle removal efficiency if the flow rate is unchanged (from the original case)? Explain your answer.

10. Filtration (18 points)

Consider the design and use of a dual media filter for drinking water treatment with the following characteristics:

- <u>Anthracite Layer</u>
  24 inch depth

  Effective Size (ES): 1.1 mm

  d_{60} size: 1.45 mm

  Porosity: 0.40

  <u>Sand layer</u>
  12 inch depth

  ES: 0.50 mm

  d_{60} size: 0.60 mm

  Porosity: 0.38

(2 Pts) What is the value of the Uniformity Coefficient for the sand media?

(4 Pts) If the design hydraulic loading rate is 5 gpm/ft^2, what is the approach, or superficial, velocity? <u>Express in units of ft/min</u>.

(6 Pts) What is the filter surface area required, and the filter width and length, for one filter to treat a flow of 2.0 MGD at the design hydraulic loading rate? Assume a length to width ratio of 1.0. Express results in English units (ft^2 and ft).

(6 Pts) At the design hydraulic loading rate, what is the clean bed head loss for the anthracite media layer for a water temperature of 60 ºF? Use the Carmen-Kozeny equation with k = 5, and use the d_{60} value for media size.

Good stuff to know

Conversions
7.48 gallon = 1.0 ft^3 1 gal = 3.7854×10^{-3} m^3
1 MGD = 694 gal/min = 1.547 ft^3/s = 43.8 L/s
1 ft^3/s = 449 gal/min
g = 32 ft/s^2
W=γ = 62.4 lb/ft^3 = 9.8 N/L
1 hp = 550 ft-lbs/s = 0.75 kW
1 mile = 5280 feet 1 ft = 0.3048 m
1 watt = 1 N-m/s
1 psi pressure = 2.3 vertical feet of water (head)
At 60 ºF, $\nu = 1.217 \times 10^{-5}$ ft^2/s

Water Properties:
At 60 ºF, $\nu = 1.217 \times 10^{-5}$ ft^2/s , μ= 2.359×10^{-5} lb-sec/ft^2 , γ = 62.4 lb/ft^3
At 10 ºC, $\nu = 1.306 \times 10^{-6}$ m^2/s , μ= 1.307×10^{-3} kg/m-s , ρ = 999.7 kg/m^3

PHYSICAL AND CHEMICAL CONSTANTS

Avogadro's number	$\mathcal{N} = 6.022 \times 10^{23}\ \text{mol}^{-1}$
Elementary charge	$e = 1.602 \times 10^{-19}\ \text{C}$
Gas constant	$R = 8.314\ \text{J mol}^{-1}\ \text{K}^{-1}$
	$= 1.987\ \text{cal mol}^{-1}\ \text{K}^{-1}$
	$= 0.08205\ \text{L atm mol}^{-1}\ \text{K}^{-1}$
Planck's constant	$h = 6.626 \times 10^{-34}\ \text{J s}$
Boltzmann's constant	$\mathbf{k} = 1.381 \times 10^{-23}\ \text{J K}^{-1}$
Faraday's constant	$F = 9.649 \times 10^{4}\ \text{C mol}^{-1}$
Speed of light	$c = 2.998 \times 10^{8}\ \text{m s}^{-1}$
Vacuum permittivity	$\varepsilon_0 = 8.854 \times 10^{-12}\ \text{J}^{-1}\ \text{C}^2\ \text{m}^{-1}$
Earth's gravitation	$g = 9.806\ \text{m s}^{-2}$

CONVERSION FACTORS

1 cal	= 4.184 joules (J)
1 eV/molecule	$= 96.485\ \text{kJ mol}^{-1}$
	$= 23.061\ \text{kcal mol}^{-1}$
1 wave number (cm^{-1})	$= 1.1970 \times 10^{-2}\ \text{kJ mol}^{-1}$
1 erg	$= 10^{-10}\ \text{kJ}$
1 atm	$= 1.01325 \times 10^{5}\ \text{Pa}$
1 Å	$= 10^{-10}\ \text{m}$
1 L	$= 10^{-3}\ \text{m}^3$

PROPERTIES OF WATER

T(°C)	ρ, Density ($\text{kg} \cdot \text{m}^{-3}$)	μ Viscosity ($\text{kg} \cdot \text{m}^{-1} \cdot \text{s}^{-1}$)	σ, Surface Tension against Air ($\text{J} \cdot \text{m}^{-2}$)	ε Dielectric Constant ($\text{C} \cdot \text{V}^{-1} \cdot \text{m}^{-1}$)	pK_w, Ionization Constant ($\text{mol}^2 \cdot \text{L}^{-2}$)
0	999.868	0.001787	0.0756	88.28	14.9435
5	999.992	0.001519	0.0749	86.3	14.7338
10	999.726	0.001307	0.07422	84.4	14.5346
15	999.125	0.001139	0.07349	82.5	14.3463
20	998.228	0.001002	0.07275	80.7	14.1669
25	997.069	0.0008904	0.07197	78.85	13.9965
30	995.671	0.0007975	0.07118	77.1	13.8330

SI PREFIXES

Multiplication Factor	Prefix	Symbol	Multiplication Factor	Prefix	Symbol
10^{12}	tera	T	10^{-2}	centi	c
10^{9}	giga	G	10^{-3}	milli	m
10^{6}	mega	M	10^{-6}	micro	μ
10^{3}	kilo	k	10^{-9}	nano	n
10^{2}	hecto	h	10^{-12}	pico	p
10^{1}	deka	da	10^{-15}	femto	f
10^{-1}	deci	d	10^{-18}	atto	a