

## BAE 452-552

### Problem set 2

Please make sure you state any assumptions that you make.

**Some of these problems are best worked on a spreadsheet! If you use a spreadsheet, please, submit results from the spreadsheet in a word document and explain what you did (including calculations). You don't need to show me all numbers that your spreadsheet used to create a graph!!**

1. (BAE 452/552) Use the differential method to evaluate the order and the constant for the data shown in the table below.

t (days)	0	2	4	6	8	10
c (mg L <sup>-1</sup> )	10.5	5.1	3.1	2.8	2.2	1.9

2. (BAE 452/552) Aside from the decomposition of organic carbon compounds, such as glucose, other reactions consume oxygen in natural waters. One such process, called nitrification, involves the conversion of ammonium (NH<sub>4</sub><sup>+</sup>) to nitrate (NO<sub>3</sub><sup>-</sup>). The reaction is as follows:



Suppose you are told that a beaker contains 12.86 g-ammonium m<sup>-3</sup> is nitrified according to the 1<sup>st</sup> order reaction

$$\frac{dn_a}{dt} = -k_n n_a$$

where  $n_a$  = ammonium concentration and  $k_n$  = 1<sup>st</sup> order rate constant for nitrification.

- (a) Convert the concentration to gN m<sup>-3</sup>.  
(b) Determine how much oxygen is consumed if the nitrification reaction goes to completion.  
(c) Calculate the rate of oxygen consumption at the start of the process ( $k_n = 0.0984 \text{ d}^{-1}$ )

3. (BAE 452/552) Using the data given below, determine the reaction-rate constant,  $k$ , and the ultimate BOD, BOD<sub>u</sub>. (Use the Thomas method)

t (days)	BOD (mg/L)
0	0
1	72
2	120
3	155
4	185
5	202
6	220
7	235

4. **(BAE 452/552)** Suppose that a waste with a discharge of  $0.3 \text{ m}^3/\text{s}$  and a BOD of  $1000 \text{ mg/L}$  enters a river with a low flow discharge of  $6 \text{ m}^3/\text{s}$ , a mean velocity of  $1 \text{ m/s}$ , and a depth of  $0.6 \text{ m}$ . The temperature of the stream-waste mixture is  $15 \text{ }^\circ\text{C}$ , and the stream is initially saturated with oxygen. The waste originates in a food-processing plant and a decomposition rate constant ( $k_d$ ) of  $0.2 \text{ day}^{-1}$  is thought to be appropriate at  $20 \text{ }^\circ\text{C}$ . A total removal rate constant  $k_r$  can be taken as  $0.32 \text{ day}^{-1}$  at  $15 \text{ }^\circ\text{C}$ .

Assuming constant discharge after the waste has been discharged, calculate the dissolved oxygen sag for the stream as it flows down river. Include a plot for at least 5 days. (how far has the mixture traveled by that time?).

5. **(BAE 452/552)** Discuss briefly the effect of changing the following parameters:
- Keeping all variables from problem 4 the same, change  $Q$  from  $6 \text{ m}^3/\text{s}$  to  $3 \text{ m}^3/\text{s}$ .
  - Keeping all variables from problem 4 the same, change  $k_r$  to  $0.05 \text{ day}^{-1}$ .
  - Keeping all variables from problem 4 the same, change  $k_a$  to  $10.0$ .
- For parts a, b, and c, provide a plot showing sag curve from problem 1 and the sag curve following the change made.
6. **(BAE 552 only)** The concentration of waste remaining unoxidized after  $t$  days is  $L_0e^{-krt}$  (or as shown in class  $L_0e^{-k_r x/U}$ ). As an exercise, calculate the effect on the oxygen sag of discharging a second waste, identical in magnitude and strength to the first one, into the river two days downstream from where the first waste was discharged. Assume constant discharge and values of  $k_r$ ,  $k_d$ , and  $k_a$  the same as in problem 1 above. Provide a new plot with  $t = 0$  as the time when the first waste was discharged.