**ENGR 118 Engineering Modeling and Analysis**

**Fall 2022**

**HOMEWORK 4:**

1. (25pts) Water flowing through an agricultural irrigation pipeline is measured every four hours over a 24hour period as shown in the provided table. The irrigation district charges the landowner based on the total volume of water consumed at a rate of $0.87/m3.
2. What is the total volume of water delivered to the agricultural field on the day the data was collected?
3. What would be the is total annual cost to the grower if they consume water in a similar pattern every day of the year?

(Note: You should consider the order of the polynomial you decide to integrate – plotting is a great way to see which order makes the most sense)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Time (h) | 0 | 4 | 8 | 12 | 16 | 20 | 24 |
| Flow Rate (m3/hr) | 0.706 | 0.623 | 1.331 | 1.821 | 1.442 | 1.842 | 0.548 |

1. (25pts) You measure the volume of water exiting a small pipe as a function of time by allowing the water to run into a graduated cylinder and marking the volume in the cylinder as a function of time as shown in the table below. Estimate the flow rate of the water at t =7s.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Time (s) | 0 | 1 | 5 | 8 |
| Volume (cm3) | 0 | 1 | 8 | 16.4 |

1. (25pts) Solve the following initial value problem over the interval from t=0 to 2.5 where y(0) = 1.
   1. Solve using Euler’s Method with a step size of 1.0, 0.5 and 0.25
   2. Solve using a higher order Runge-Kutta method (i.e. ‘solve\_ivp), with a step size of 1.0, 0.5 and 0.25
   3. Plot the results of ‘a’ and ‘b’ on the same graph (i.e. six plots on one graph). Each method should have its own color and each step size should have its own line style.
   4. Based on what you know about the two methods and step sizes, which plot is the most accurate?
2. (25pts) The below figure shows a continuous flow stirred tank reactor to grow a bacterial culture. The mass balances for the bacterial biomass, X (g/m3), and the substrate concentration, S (g/m3), can be written as:

A picture containing text, sky

Description automatically generatedDiagram

Description automatically generated

A screenshot of a computer

Description automatically generated with low confidence

(Hint: your output should be three plots of X and S as a function of time 0-100 hr)

Optional Extra Credit (5pts) – for each plot in Question 4 include a second y-axis (i.e. so X and S have their own y-axis on the same plot). I have not shown you how to do this – you will have to search/figure it out on your own.

1. Optional - Extra Credit (10pts)

Using any numerical methods covered in this course, write a homework problem, and solve it using Python. Your problem can use made up data, should have clear annotation throughout, and should involve one of the numerical methods we have discussed in this class. Be explicit about which numerical method you are using. (Your problem should be of homework question caliber – e.g. a question that you can answer with two lines of code will not suffice)