

# CS1112 Spring 2011 Project 2    due Thursday 2/17 at 11pm

You must work either on your own or with one partner. If you work with a partner you must first register as a group in CMS and then submit your work as a group. *Adhere to the Code of Academic Integrity.* For a group, “you” below refers to “your group.” You may discuss background issues and general strategies with others, but the work that you submit must be your own. In particular, you may discuss general ideas with others but you may not work out the detailed solutions with others. It is not OK for you to see or hear another student’s code and it is certainly not OK to copy code from another person or from published/Internet sources. If you feel that you cannot complete the assignment on your own, seek help from the course staff.

## Objectives

Completing this project will solidify your understanding of Chapters 2 and 3 in *Insight* (for-loops, while-loops, nested loops). In problem 2 you will also work with MATLAB graphics.

## Ground Rule

The use of arrays and the `break` command is *not* allowed. In fact, do not use `break` in this course.

## 1 Stars

Complete Problem **P2.2.9** in *Insight* (page 43). Use `fprintf` with appropriate format sequences to print the requested table. By “table” we mean that the columns of numbers should line up neatly. Save your script in a file `stars.m` and submit it on CMS.

## 2 Oxygen Please

One indicator of the well being of rivers is the concentration of dissolved oxygen (DO) in the water. The US Environmental Protection Agency determines DO guidelines that are appropriate for different uses of the streams. For example, recreational fisheries require DO concentrations above 8 mg/l. Rivers have a “cleaning capacity” in that they consume pollutants through biological processes. These biological processes deplete DO, but fortunately for all living things the level of DO recovers naturally in a process called reaeration!

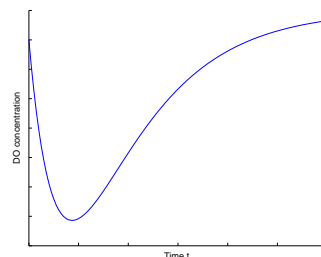
The depletion and reaeration of DO can be modeled by the “DO sag equation” of Streeter and Phelps:

$$c(t) = c_s - \frac{L_0 K_d}{K_a - K_r} [\exp(-K_r t) - \exp(-K_a t)] - (c_s - c_0) \exp(-K_a t) \quad (1)$$

where  $t$  is time (independent variable),  
 $c(t)$  is the DO concentration at time  $t$ ,  
 $c_s$  is the DO saturation concentration (maximum possible DO given temperature and pressure),  
 $c_0$  is the initial DO concentration,  
 $L_0$  is the pollutant Load into a river,  
 $K_d$  is the rate of decay of pollutants through biological processes,  
 $K_r$  is the rate of removal of pollutants through biological processes and settling, and  
 $K_a$  is the rate of reaeration.

This model gives the “DO sag curve” due to a polluting event and has the typical shape shown on the right—initial DO depletion due to biological activities followed by recovery due to reaeration.

Write a MATLAB script `oxygenCurve.m` to simulate the DO level using the above model and plot the DO curve. The simulation starts at  $t = 0$ , the time of the polluting event, and ends when the DO level returns to the initial level, when the maximum simulation time of 10 days is reached, or if anaerobic condition (DO level of zero) occurs, whichever happens first. Your code determines the minimum DO level, the time of minimum DO, and recovery time (if within 10 days) and displays those values on the plot.



## Additional Specifications and Hints

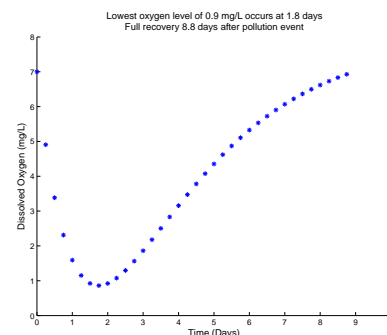
- Use these river data and model parameter values for program development:  $L_0 = 30$  mg/l,  $c_s = 8$  mg/l,  $c_0 = 7$  mg/l,  $K_d = 0.35$ /day,  $K_r = 0.35$ /day,  $K_a = 0.8$ /day.
- *Decompose the problem!* (1) Start with plotting the DO curve. Plot each DO value as it is calculated using a marker. An example plot is shown below. Think carefully about how to control the duration of the simulation—there are several conditions that may terminate the simulation. (2) Add code to determine the minimum DO level and the time at which it occurs. Write code to determine these values in the simulation; do *not* solve for them using Calculus!
- Set reasonable parameter values. For example, the model parameters involving time are in days and the maximum simulation duration is 10 days, so reasonable values for a time step may be a few hours to a day. At discrete times, the calculated DO value likely would not be the exact target value so a tolerance should be set, say, at order of 0.1 mg/l. *Practise good programming style* by naming all parameters as variables.
- *Graphics and output* Use these commands to set up the figure window:

```
close all           % Close all figure windows
figure             % Start new figure window
axis([0 uBound 0 c0+1]) % X-axis limits 0 to uBound; y-axis limits 0 to c0+1
hold on           % Hold subsequent plot commands on current axes (window)
xlabel('Time (Days)', 'FontSize',12)
ylabel('Dissolved Oxygen (mg/L)', 'FontSize',12)
```

Note that `uBound` and `c0` above are variables and you need to initialize them first. Use the `plot` command to plot each DO value. Recall that `plot(a,b,'r*')` puts a red asterisk at coordinates  $(a, b)$ . Use any marker and color you like. Use the command `hold off` at the end of the script. The title of the plot should indicate the minimum DO value, the time of minimum DO, and/or the status of DO recovery. Below are four example “titles” of the plot; depending on the model parameters your code should output the appropriate message with calculated values:

- Anaerobic condition at 2.5 days
- Lowest oxygen level of 2.1 mg/L occurs at 3.0 days  
Full recovery 9.0 days after pollution event
- Lowest oxygen level of 2.1 mg/L occurs at 3.0 days  
Full recovery not reached after 10.0 days
- Oxygen level continues to drop after 10.0 days

“Full recovery” refers to the DO level returning to the initial value.



Be sure to run your program with different parameter values to make sure that it works for the different scenarios. We suggest three test cases as shown on the right; try other cases as well. After testing set the parameters back to case 1 values and submit your file `oxygenCurve.m` on CMS.

Case	$K_d$	$K_r$	$K_a$
1	.35	.35	.8
2	.25	.25	.6
3	.05	.05	.1

**Aside** Of the three rates—decay, removal, and reaeration—to which is the result most *sensitive*? I.e., changes in which rate cause the biggest change in DO concentrations? There is no need to submit an answer to this question, but do realize that changes in parameter or other input values *do* change the computed results. The goal of computing isn’t some numeric answer; it is insight into a problem. For example, knowing the sensitivity of the model to the reaeration rate, i.e. how a change in the reaeration rate affects the minimum DO, is as important as knowing—estimating—the minimum DO value itself.

## 3 What’s the Pattern?

Complete Problem **P3.2.7** in *Insight* (page 60) and display the output neatly. Save your script as `sequence.m` and submit it on CMS.