

# CEE 3804 Quiz 3

## Computer Applications in CEE

### Open Book and Notes (Take Home)

Your Name \_\_\_\_\_

VT Number \_\_\_\_\_

Your Signature \* \_\_\_\_\_

\* The answers in this exam are the product of my own work. I certify that I have not received nor I have provided help to others while taking this examination.

**Directions:**

Solve the problems. Copy and paste the Matlab code and solutions such as graphs in a Word Document. Label your Word document as follows: Problem 1, Problem 2, etc. Start a new page in every problem solution. When the exam is completed, mail to: [vuela@vt.edu](mailto:vuela@vt.edu) and [moisesbm@vt.edu](mailto:moisesbm@vt.edu). Include in the email subject line: CEE 3804. Write your name in every page just in case.

## Problem 1 (40 points)

A problem for construction engineers and developers specializing in land development is the dynamics between the available land and time to develop industries in an area. An equation to predict industrial development (i.e., number of industries over time) for a **new 500-acre industrial** park in North Carolina is shown below:

$$\frac{d(I)}{dt} = \frac{(I)(V_{ac})(A)}{(L_{ind})(T_c)} - \frac{I}{T_U}$$

$$V_{ac} = L_Z - O_{cc}$$

$$O_{cc} = I(L_{ind})$$

where:

$I$  = Industries

$\frac{d(I)}{dt}$  = rate of change of number of industries over time (industries/year)

$V_{ac}$  = Vacant land area (acres)

$A$  = Attraction factor (1/industry)

$T_U$  = Useful industry time (year)

$L_{ind}$  = Land per industry (acre/industry)

$T_c$  = Time to construct (year)

$L_Z$  = Land zoned for industry (acres)

$O_{cc}$  = Occupied land (acres)

$$L_{ind} = 8; \quad (\text{acres/industry})$$

$$A = 0.01; \quad (1/\text{industry})$$

$$T_U = 15; \quad (\text{yr})$$

$$T_c = 2; \quad (\text{yr})$$

### Task 1:

Create a Simulink to model the system and to predict the number of industries ( $I$ ) as a function of time ( $t$ ).

### Task 2:

Solve the differential equation if today there are 3 industries established at the industrial park. Comment on the shape of the response obtained. According to this model, find the time to have 90% of the industrial park occupied by various industries. Plot in Matlab the number of industries as a function of time.

### Task 3:

If each industry renting space in the park pays an average rent of \$4000 per acre per month, estimate the time to recover the development cost if the developer spends an average of 2.5 million per industry. This includes the cost of constructing buildings and roads to service the industrial park. Program the rent and revenue to the developer in your Simulink model. Plot the results in Matlab. Use as much of your engineering economy knowledge as possible.

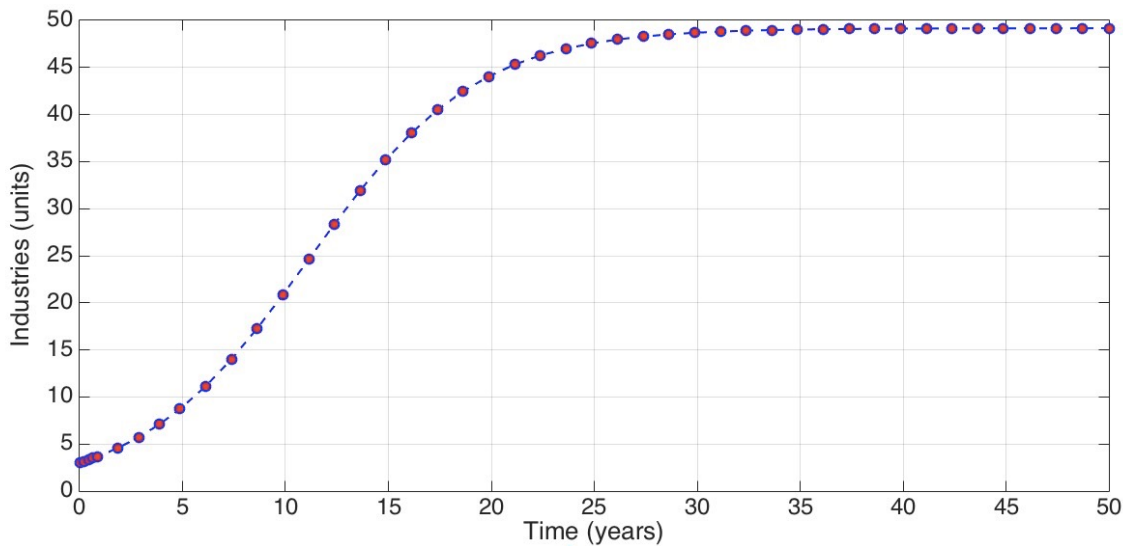


Figure 1. Number of Industries vs. Time. Numerical Solution Using Matlab RK45 Solver.

Solving the differential equation for steady-state conditions (the change in industries is zero at steady-state),

$$\frac{d(I)}{dt} = 0 = \frac{(I)(V_{ac})(A)}{(L_{ind})(T_c)} - \frac{I}{T_U}$$

where :

$$V_{ac} = L_Z - O_{cc}$$

$$O_{cc} = I(L_{ind})$$

substitute the values of  $V_{ac}$  and  $O_{cc}$  into the first equation:

$$\frac{(I)(L_Z - I(L_{ind}))(A)}{(L_{ind})(T_c)} = \frac{I}{T_U}$$

$$\frac{(I)(L_Z)(A)}{(L_{ind})(T_c)} - \frac{I^2(A)}{(T_c)} = \frac{I}{T_U}$$

$$\frac{(I)(500 - 8 * 3)(0.01)}{(8)(2)} - \frac{I}{15} - \frac{I^2(0.01)}{(2)} = 0$$

$$\frac{(I)(500)(0.01)}{(8)(2)} - \frac{I}{15} - \frac{I^2(0.01)}{(2)} = 0$$

$$0.3125(I) - 0.0667(I) - 0.005(I^2) = 0$$

$$0.2458(I) - 0.005(I^2) = 0$$

This is a polynomial of degree 2. Use Matlab to setup a polynomial with coefficients P.

$$P = [-0.005 \ 0.2548 \ 0]$$

Find the roots of the polynomial in Matlab:

```
>> roots (P)
```

**The roots of the polynomial are 0 and 49.16.** The first solution is trivial and hence ignored (i.e., industries cannot be zero since we started with 3 industries at time  $t=0$ ). The second steady-state solution found (49.16) correlates well with the solution obtained in Simulink and shown in Figure 1.

You can find the time to reach 90% of the steady-state solution. Let “tstar” be the time when industries reach the 90th percentile point. This means 44.2 industries established at the industrial park. Use Matlab interpolation function to find that time. This assumes that you have two vectors in the workspace that represent time (t) and industries over time (I).

```
>> tsta=interp1(I,t,ans)
```

**tstar = 20 years.**

#### Task 4:

According to this model, estimate the number of industries established at the industrial park after 15 years of operation. Would it be useful to reduce the the time for construction by 15% to improve the finances for this engineering/ developer team? Explain. Plot the baseline and the new solution in the same plot to facilitate a comparison.

Reducing the construction time by 15% ( $T_c = 1.7$  years) produces a faster growth in the number of industries as a function of time. The solution is shown in Figure 2. The number of industries established at the park will increase from 35 to 43.

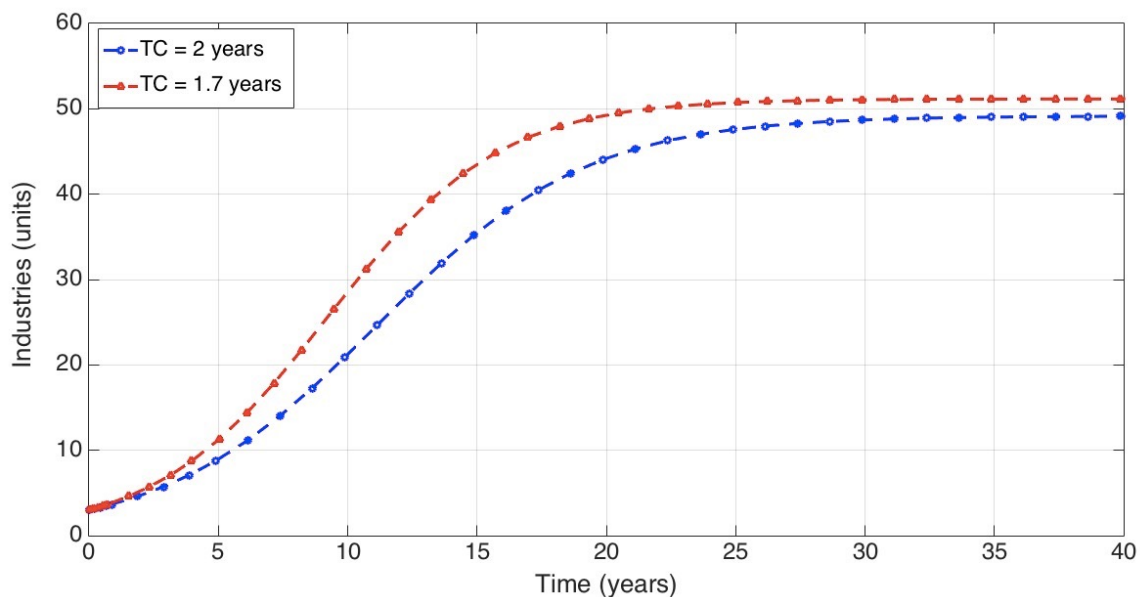


Figure 2. Time Solution of the Number of Industries at Industrial Park for two Values of Construction Time ( $T_c$ ).

## Problem 2 (30 points)

Virginia Tech students traveled to Punta Cana last year to help the airport authority to estimate sound levels around communities near the airport. The following data was collected during a single flyover landing event of an Airbus A320 at Punta Cana (see picture).



Figure 1. Single Flyover Event at Punta Cana Airport.

Table 1. Single Flyover Noise Event Data for Airbus A320.

Time of measurement (seconds)	Sound Pressure Level (dBA)	Time of measurement (seconds)	Sound Pressure Level (dBA)
1.00	71.50	11.00	86.80
2.00	72.50	12.00	87.30
3.00	74.60	13.00	84.90
4.00	75.60	14.00	82.00
5.00	77.70	15.00	79.10
6.00	76.00	16.00	76.10
7.00	76.50	17.00	74.50
8.00	77.80	18.00	72.10
9.00	78.00	19.00	71.80
10.00	84.10	20.00	68.90

The Sound Exposure Level (SEL) - a value used in the assessment of noise around airports - is defined as:

$$SEL = 10 \log \left[ \int_{t_1}^{t_2} 10^{SPL(t)/10} dt \right] \quad (1)$$

$SEL$  = Sound Exposure Level (dBA)

$SPL$  = Sound Pressure Level measured by an instrument (dBA)

$t_1$  and  $t_2$  are two time intervals to measure the value of SEL

The process is illustrated in Figure 3.

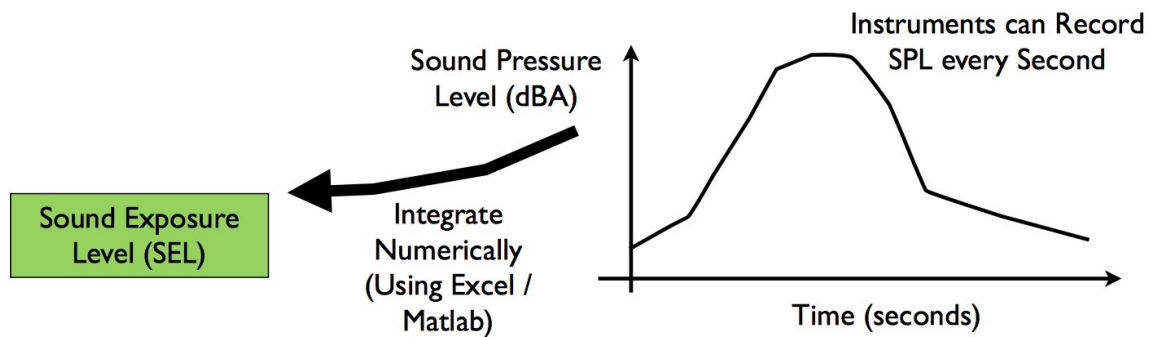


Figure 3. Sound Pressure Level Sketch to Understand the Value of SEL.

### Task 1:

Create a Matlab script to integrate numerically the values of SPL provided in the table using the formula shown in Eq. (1). In your numerical integration assume  $t_1$  is the first value in Table 1 and  $t_2$  is the last one. To make the process simple, integrate using the trapezoidal function in Matlab.

I created a data file with the values shown in Table 1. The values are stored in a file called **splSignal.m**. A sample of the file is shown below.

```
% Data with values of Sound Pressure Level (SPL)
% Column 1 = time (seconds)
% Column 2 = SPL (dBA)
1.00 71.50
2.00 72.50
```

The script to carry out the computations is shown below:

```
% Script to integrate numerically the values of SPL as a function of time.
% A. Trani (April 24, 2015)
% Load the file with SPL vs time data
load splSignal.m
```

```

% Data with values of Sound Pressure Level (SPL)

% Column 1 = time (seconds)

% Column 2 = SPL (dBA)

% 1.00 71.50

% 2.00 72.50

% Create two variables to perform the calculations.

time = splSignal(:,1);

SPL = splSignal(:,2);

% Use equation for SEL and integrate numerically.

% SEL = 10* log10 [ integral of (10 ^ (SPL/10) dt) ]

% Let: area = integral(10^(SPL/10) * dt)

area = trapz(10.^(SPL/10)); % area under curve between t1 and t2

SEL = 10*log10(area);

clc

disp(['Sound Exposure Level Value is ',num2str(SEL), ' dBA' ])

```

### Task 2:

Find the value of SEL (in dBA) for this single flyover. The value is produced in the Command Window.

**>> Sound Exposure Level Value is 93.58 dBA**

**In the calculations, verify that the value of area = 2282368924.4 (dbA-seconds)**

### **Problem 3 (30 points)**

Take a relatively complex problem from one of your other classes and do the following:

#### **Task 1:**

Create a Matlab function to perform some calculation that is repetitive. The Matlab function should **produce at least two outputs** and be related to another CEE class.

#### **Task 2:**

Create a Matlab script that calls the Matlab function created in Task 1 multiple times (either in a loop or just vector calculations). Demonstrate that your function works and create graphical of the answers obtained. Comment your code carefully indicating what is an input and what is an output.