# CEE 3804 Final Exam (Spring 2021)

# Computer Applications in CEE

# Open Book and Notes (Take Home)

Your Name ______________________________________________

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 and VBA code and solutions such as graphs in a Word Document and convert to a single PDF file. **Make sure your code is not too small for me to be able to read it.**

## Problem 1 (25 points)

Using your knowledge of Simulink, solve the differential equation of the cooling process of Hot Mix Asphalt (HMA) - commonly used material to pave roads. The Simulink model should solve the first-order differential equation that models the temperature variation of Hot Mix Asphalt (HMA) as a function of time. The differential equation is:

$$\frac{dT}{dt} = -H(T - T_a)^n$$

subject to initial conditions such that:

$$T(t=0) = T_o$$

where:

$H =$ cooling constant of the asphalt mixture

$H = 0.040$ (1/minute)

$T =$ Temperature of the asphalt mixture (deg. C)

$T_0 =$ Initial Temperature of the asphalt mixture (deg. C)

$T_a =$ Ambient Temperature (deg. C)

$n =$ empirical constant (dimensionless)

### Task 1

Create a Simulink model to model the HMA cooling process.

### Task 2

Run the Simulink model created in Task 1. Verify with solutions obtained in Problem 1 that the model works as expected. The ambient temperature during HMA mixture lay down is 9 deg. C and the initial temperature of the asphalt mixture is 185 deg. C at the site. Empirical lab analysis reveals a value of $n$ to be 0.86.

a) Export the state variables to the Simulink model to the Matlab and plot the HMA temperature vs. time (**a plot using the Simulink scope is not acceptable for this task**). Label accordingly.

b) Using the model developed, find the time for the HMA mixture to reach 5% above the ambient temperature. You can do this graphically if desired.

### Task 3

Verify the solution of the Simulink model developed by performing steady-state hand-calculations for the problem.

**Problem 2 (25 points)**

A common model used in engineering and meteorology to estimate the temperature ($T$), density ($\rho$) and pressure ($P$) in the atmosphere is shown below. The model consists of three equations to estimate temperature, density and pressure. The metric units in this model are all consistent.

$$T = T_0 + \lambda(h - h_o)$$

where:

$T$ = air temperature (deg. Kelvin)

$T_0$ = air temperature at sea level (deg. Kelvin)

$\lambda$ = is the temperature lapse rate (i.e., change) with altitude (deg. Kelvin per meter)

$h$ = is the altitude (in meters) at which we want to know the atmospheric variables

$h_0$ = is the value of the sea level reference altitude (meters)

$$\rho = \rho_0 \left( \frac{T}{T_0} \right)^{\left( \frac{-g}{R\lambda} - 1 \right)}$$

where:

$\rho$ = is the air density (kg/m$^3$)

$\rho_0$ = is the sea level air density (kg/m$^3$)

$g$ = is the gravity constant (m/s$^2$)

$R$ = is a universal gas constant (N-m/deg. K)

$T$ = air temperature (deg. Kelvin)

$T_0$ = air temperature at sea level (deg. Kelvin)

also

$$P = P_o \left( \frac{\rho}{\rho_0} \right) \left( \frac{T}{T_0} \right)$$

where:

$P$ = is the atmospheric pressure at altitude (N/m$^2$)

$P_0$ = is the atmospheric pressure at sea level conditions (N/m$^2$)

$\rho$ = is the air density (kg/m$^3$)

$\rho_0$ = is the sea level air density (kg/m$^3$)

$T$ = air temperature (deg. Kelvin), and

$T_0$ = air temperature at sea level (deg. Kelvin)

The numerical values of sea level conditions are given in the table below:

*Table 1. Numerical Constants of Standard Atmospheric Model.*

| Constant | Value |
|---|---|
| $T_0$ | 288 deg. Kelvin |
| $\rho_0$ | 1.225 kg/$m^3$ |
| $P_0$ | 101,325 N/$m^2$ |
| $\lambda$ | -0.0065 Kelvin/meter |
| $R$ | 287 N-m/deg. K |
| $g$ | 9.81 m/$s^2$ |
| $h_0$ | Mean sea level condition (0 meters) |

## Task 1

**Create a Matlab function** that estimates the values of temperature ($T$), density ( $\rho$ ) and pressure ( $P$ ) in the atmosphere for a given altitude ($h$). In this analysis assume the mean value of the reference altitude ($h_0$) is zero. Your function has 3 outputs and one input.

Test your function with values of $h = 0$ and 5000 meters. State the values of temperature ($T$), density ( $\rho$ ) and pressure ( $P$ ) in the atmosphere.

## Task 2

**Create a Matlab script** and use (i.e., call) the function created in Task 1. The script should do the following:

a) Create a vector of altitudes ranging from sea level conditions to 13,000 meters at steps of 250 meters.

b) Estimate the values of temperature ($T$), density ( $\rho$ ) and pressure ( $P$ ) in the atmosphere for a given altitude ($h$).

c) Plot the results in three viewports on the same figure (one figure) to show the variations of ($T$), ( $\rho$ ) and ( $P$ ) with altitude altitude.

## Task 3

Improve the script created in Task 2 to find and plot (in a separate figure) the values of air density below 0.60 kg/$m^3$ against altitude. State the altitude at which the density is equal to 0.60kg/$m^3$. Use interpolation functions if necessary.

**Include screen captures of Matlab code required to create the function and the script itself.**

## Problem 3 (25 points)

### Task 1

Using a variation of the temperature equation of the atmospheric model described in Problem 2 (and partially repeated below), **create a function** in Microsoft Excel to estimate the atmospheric temperature ( $T$ ) given the altitude ( $h$ ) above sea level. The units in this model are all consistent and are metric units. Use the values needed from Table 1 in solving this problem.

$$T = \begin{cases} T_0 + \lambda(h - h_o) & \text{if } h \leq 11{,}000 \text{ m} \\ 216.5 \text{ deg. K if } h > 11{,}000 \text{ m} \end{cases}$$

where:

$T$ = air temperature (deg. Kelvin)

$T_0$ = air temperature at sea level (deg. Kelvin)

$\lambda$ = is the temperature lapse rate (i.e., change) with altitude (deg. Kelvin per meter)

$h$ = is the altitude (in meters) at which we want to know the atmospheric variables

$h_0$ = is the value of the sea level reference altitude (meters)

### Task 2

Use Excel to test the function created in Task 1. Create a column of altitude values ranging from 0 to 13,000 meters at intervals of 250 meters. Use the Excel function created in Task 1 to calculate the value of temperature for each altitude included in the altitude column.

**Include screen the code required to create the Excel function.**

**Problem 4 (25 points)**

The following linear programming problem has been developed to predict resource allocation at a company.

$$\text{Max Z} = 380x_1 + 200x_2$$

subject to:

$$x_1 \le 100$$

$$230x_1 + 120x_2 \le 44000$$

$$10x_1 + 20x_2 < 5400$$

$$x_1 \text{ and } x_2 \ge 0$$

### Task 1

Convert the problem shown above into **standard (canonical) form** to be solved by hand using the Simplex Method. Write down the transformed equations and add slack and artificial variables as needed.

### Task 2

Use the manual steps of the Simplex Method to solve this problem. Indicate the values of all the variables in every table. Indicate the value of the objective function Z in every table. This task requires hand calculations. Show me all the tableaus.

### Task 3

Solve the problem using Excel Solver to verify your answer.