CEE 3804 Final Exam (Spring 2023)

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.** Please make sure the plots are visible and all code should have a font size of 12.

Problem 1 (30 points)

A civil engineer is designing acceleration ramps for a new highway. Figure 1 who's the typical acceleration ramp configuration. The highway is used by a variety of vehicles including cars, light trucks, and heavy trucks. The engineer collected data about three types of vehicles to design the acceleration ramp (L) shown in Figure 1.
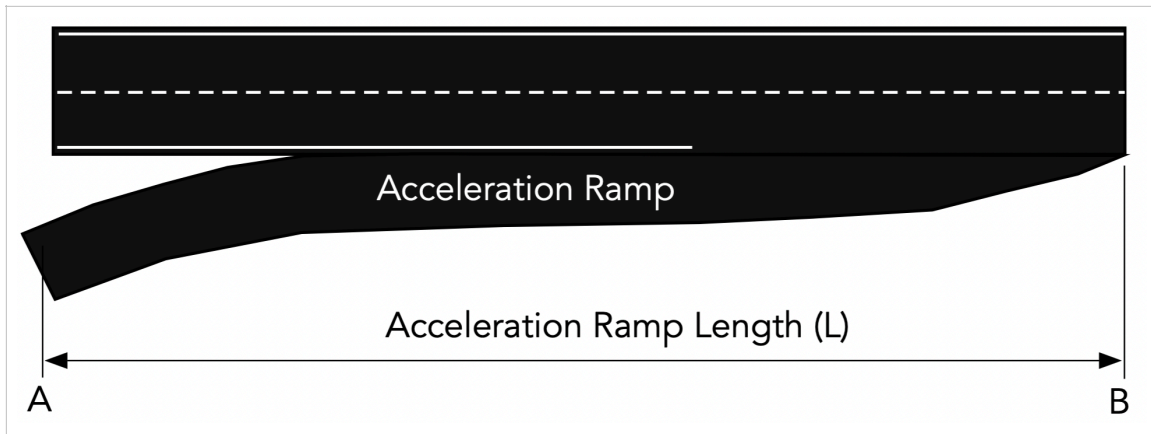

Figure 1. Highway Ramp Scenario for Problem 1.

Using your knowledge Matlab ODE solvers or Simulink (your choice), to solve the differential equations of a vehicle accelerating on the highway ramp. The Simulink model should solve the first-order differential equation of acceleration of the vehicle for a given set of vehicle parameters (k_1 and k_2). Table 1 has the parameters for three types of commonly used highway vehicles. The differential equation is presented below.

$$\frac{dV}{dt} = k_1 - k_2 V^n$$

Where:

$\frac{dV}{dt}$ is the vehicle acceleration in m/s²

k_1 is the first acceleration constant (m/s²)

k_2 is the second acceleration constant (in 1/s)

V is the speed of the vehicle (m/s)

n is an empirical factor derived from vehicle testing (dimensionless)

Table 1. Shows shows the acceleration constants for three types of highway vehicles using empirical data.

Table 1. Acceleration Constants for the Three Types of Highway Vehicles.

Vehicle Type	k_1	k_2	n
Mid-size Sedan	2.1	0.045	0.95
Light Truck (loaded)	1.9	0.048	0.87
Heavy Truck (loaded)	1.1	0.031	0.89

Task 1
Create Matlab code (using ODE solver) or a Simulink model to solve the differential equation that estimates vehicle speed as a function of time.

Task 2
Enhance the model of Task 1 to predict the distance travelled by the vehicle accelerating on the ramp.

Task 3
Use the heavy truck and mid-size sedan car parameters to estimate the distance (L) between points A and B in Figure 1 allowing the vehicle to reach a top speed of 30 m/s (~ 65 mph) at the merging position B. Present both estimates running the model with the appropriate values of k_1 and k_2. Assume the vehicle initial speed at point A is 5 m/s (low speed).

Include screen captures of Matlab code or Simulink model and plots needed to estimate the acceleration ramp length (L).

Problem 2 (40 points)

Task 1
A common model used in engineering and meteorology to estimate the temperature (T), density (ρ) 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. Table 2 shows the numerical constants needed to solve the 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)

λ = 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:

ρ = is the air density (kg/m^3)

ρ_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)

ρ = is the air density (kg/m^3)

ρ_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)

Table 2. Numerical Constants of Standard Atmospheric Model.

Constant	Value
T_0	288 deg. Kelvin
ρ_0	1.225 kg/m³
P_0	101,325 N/m²
λ	-0.0065 Kelvin/meter
R	287 N-m/deg. K
g	9.81 m/s²
h_0	Mean sea level condition (0 meters)

Task 1

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

Test your function with values of $h = 0$, 1560, and 13200 meters. State the values of temperature (T), density (ρ) and pressure (P) in the atmosphere at the testing altitudes. You can validate the answers using public web sites like: https://www.digitaldutch.com/atmoscalc/

Task 2

Create a Matlab script that uses the function created in Task 1 to estimate the atmospheric variables and plot them against elevation. 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 (ρ) 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), (ρ) and (P) with altitude.

Include screen captures of Matlab code required to create the function and the script itself. Also include all plots.

Problem 3 (30 points)

The following linear programming problem has been developed to predict the production of concrete beams made of two materials at a company. x_1 and x_2 represent the quantities of high-strength and low-strength concrete beams, respectively.

$$Z = 310x_1 + 238x_2$$

$$220x_1 + 120x_2 <= 39000$$

$$10x_1 + 23x_2 <= 4100$$

$$x_1 + 1.3x_2 <= 230$$

$$x_1 >= 0 \text{ and } x_2 >= 0$$

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.