Assignment 7: Functions and Numerical Integration

Date Due: April 10, 2011   Instructor: Trani

Problem 1

A civil engineer is designing a rainstorm water management system for a shopping mall. During a severe thunderstorm, the water runoff generated by the large parking lot at the shopping mall is given by the function:

$$runoff = k_2 + k_1 \sin(t / k_3)e^{(-t/k_4)}$$

Where *runoff* is the runoff volume (cubic meters per second) generated by the parking lot, *t* is the time (in seconds) after the thunderstorm starts and k_1 through k_4 are parameters of the runoff function.

Task 1

Create a Matlab function to calculate the runoff for a given value of time t. As part of the input variables to the function runoff, include the four input parameters k1 through k4 for a 100 year storm with numerical values as follows:

k1 = 65;
k2 = 2;
k3 = 750;
k4 = 400;

Task 2

Create a Matlab script to call the function created in Task 1. Test the function for values of time (t) starting at t=0 and ending at t=3000 seconds. Plot the runoff as a function of time. Label appropriately.

Task 3

Modify the Matlab script created in Task 2 to find the area under the curve of the runoff as a function of time. Use the Matlab "quad" function to estimate the integral. Plot the results and output the result of the area under the curve in the command window using the "disp" function in Matlab. How much runoff is produced in the 3000 second storm event? State the units of the answer.

Task 4

Estimate the dimensions of a ponding volume needed to store all the runoff volume generated by the 100 storm event. State dimensions of the ponding volume (base x width x height).

Problem 2

The Manning equation is a simple empirical relationship used by civil engineers to estimate the flow characteristics inside pipes. The basic Manning Equation is:

$$Q = [1.486\ A * R^{\wedge}(2/3) * S^{\wedge}(1/2)] / n$$

where:

Q is the discharge (in cubic feet per second)

R is the hydraulic radius (ft : area of section / wetted perimeter)

S is the slope of the pipe invert (ft/ft)

A is the cross sectional area of flow (ft-ft)

n is the pipe roughness coefficient (see table below)

    Table 2. Typical pipe roughness coefficients.

Type of Pipe	Roughness Coefficient
Concrete and asbestos	0.012
Corrugated metal	0.023

Task 1
Create a function to estimate Q in the Manning equation given all four parameters (A, R, S and n). In this function the fourth parameter (n) must be passed to the function as a string variable (i.e., either 'concrete' or 'metal') with the name of the pipe type. Inside your function detect the pipe type and assign the corresponding value of the pipe roughness coefficient (n). Test the function with the following values: S=0.2 ft/ft, R =15 inches and concrete pipes.

Task 2
Create a Matlab script and use the function created in Task 1 to generate solutions to the Manning equation for circular pipes (one for concrete and one for metal) flowing at full flow wetted areas (with radii ranging from 12-100 inches) and slopes ranging from 1 foot per 5 feet to 1 foot to 50 feet (0.2 to 0.02). Create a mesh plot in Matlab that shows the discharge (in z-axis), the slope (in y-axis) and the radius of the pipe in the x-axis for the ranges stated above.

Problem 3

A train engineer collects data during the certification of the new high-speed train to be introduced in the Northeast Corridor in the United States. The data collected records train acceleration (a) vs. velocity (V). The data is presented in the table below.

Table 1. Train Acceleration and Speed Data.

Train Velocity (m/s)	Maximum Train Acceleration (m/s^2)
0.00	2.1
20	1.56
30	1.30
40	1.06
50	0.76
60	0.51
80	0.00

Task 1
Create a Matlab script to plot the data and (in the same script) to find the best second order polynomials that fit the data (i.e., use the "polyfit" command). Save the coefficients of the polynomials and evaluate 100 data points of these polynomials across a range of speeds from 0-80 m/s (the usable operating speeds for this train). Compare with the original data.

Task 2
Using the best fit polynomials estimated in Task 1, evaluate the goodness of fit of the polynomial by calculating the residuals or the local differences between the data points provided and the points of the acceleration function A(V) approximated by the fitted polynomial. Find the sum of the square errors of the fitted data and comment on the solution obtained. Is this a good fit? Tell me why.

Problem 3

A civil engineer sends you a "comma separated" data file containing aircraft characteristics used in airport design. The first few lines of the file look as follows:

Adam Aircraft Industries,A500,7000 ,98,44.00,9.58

Aero Spacelines,B-377,170000 ,123,156.25,48.50

Aeronca,11AC Chief,1250 ,64,36.00,6.00

Aeronca,15AC Sedan,2050 ,67,37.50,10.33

Aerospatiale,ATR-42-320,36817 ,124,80.58,24.92

The six columns of each record are explained below. The file name is "aircraft_characteristics_noheader_csv.csv".

Column 1 = aircraft name

Column 2 = manufacturer name

Column 3 = aircraft takeoff weight (lb)

Column 4 = aircraft approach speed (nautical miles per hour)

Column 5 = aircraft wingspan (feet)

Column 6 = aircraft tail height (feet)

Task 1
Create a Matlab script to read the complete data in this file in 6 column format. Use the Matlab "textscan" command with a comma delimiter. This information will be used in Task 3.

Task 2
Create a Matlab function to assign a "wake" class (i.e., a string variable) and the airplane design group class (another string variable) to an aircraft according to their takeoff mass, wingspan and tail heights. According to the Federal Aviation Administration (FAA) the following rules are used by Air Traffic in assigning wake classes:

Small if takeoff weight < 41,000 lb
Large if takeoff weight >=41,000 lb and <= than 255,000 lb
Heavy if takeoff weight > 255,000 lb
Superheavy if takeoff weight > 1,000,000 lb

Similarly, the FAA groups aircraft according to their wingspan and tail height using the following letter designation (called aircraft design groups as shown in column 1 of the table):

Table 1-1. Airplane Design Groups (ADG)

Group #	Tail Height (ft)	Wingspan (ft)
I	<20	<49
II	20 - <30	49 - <79
III	30 - <45	79 - <118
IV	45 - <60	118 - <171
V	60 - <66	171 - <214
VI	66 - <80	214 - <262

The function should take as parameters the aircraft takeoff weight, the aircraft wingspan and the tail height and return two strings: a) wake class and b) the FAA airplane design group.

Task 3
Modify the Matlab script created in Task 1 and using the function created in Task 2, assign the wake classes and airplane design groups to the complete list of aircraft read in Task 1.

Task 4
Modify the Matlab script created in Task 3 and using the string comparison function in Matlab extract all aircraft that are class "Large" and that belong to airplane design group III. Plot their aircraft wingspan and tail height.