CEE 3804 Exam2 (Spring 2024)

Computer Applications in Civil Engineering

Open Book and Notes -

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 computer 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.** Minimum font size 10.

Problem 1 (30 points)

Electric and natural gas-powered vehicles require charging stations along highways in the United States. Figure 1 shows sample data for several types of charging stations including electric (ELEC) and natural gas (CNG) stations.

	A	B	C	D	E	F	G	H
1	**Fuel Type Code**	**Station Name**	**Street Address**	**ntersection Directions**	**City**	**State**	**Latitude**	**Longitude**
2	CNG	Arkansas Oklahoma Gas	2100 S Waldron Rd		Fort Smith	AR	35.36	-94.38
3	CNG	Clean Energy - Logan Inte	1000 Cottage St Ext	From Route 1, take the	East Boston	MA	42.37	-71.03
4	CNG	Clean Energy - Everett - N	16 Rover St	Rt 16, exit to Rt 99, to D	Everett	MA	42.39	-71.06
5	CNG	Clean Energy - Greenpoin	287 Maspeth Ave	I-278/Brooklyn Queens	Brooklyn	NY	40.72	-73.93
6	CNG	Canarsie - National Grid	8424 Ditmas Ave	From Shore Pkwy, take	Brooklyn	NY	40.65	-73.92
7	CNG	Con Edison - Van Nest Se	1615 Bronxdale Ave	Hutchinson River Park	Bronx	NY	40.84	-73.86
8	CNG	Con Edison - Rye Service	178 Theodore Fremd Ave	I-95/New England Thru	Rye	NY	40.98	-73.69
9	CNG	Con Edison - College Poin	124-15 31st Ave	From I-678/Whitestone	Queens	NY	40.77	-73.84
10	CNG	CNG Source Fueling - Gre	111 W Raymond St	I-65, exit onto Raymon	Indianapolis	IN	39.74	-86.16
11	CNG	Black Hills Energy	1301 W 24th St	From I-25 take exit 10,	Cheyenne	WY	41.14	-104.83
12	CNG	Clean Energy - City of San	2931 Rufina St		Santa Fe	NM	35.66	-105.99
13	CNG	Kansas Gas Service	11401 W 89th St	Station located in Servi	Overland Park	KS	38.97	-94.72
14	CNG	Kansas Gas Service	200 E 1st Ave		Topeka	KS	39.06	-95.67

Figure 1. Sample Car Power Station Data.

a) Create a Matlab script to read the data. Label the variables appropriately and include their units if applicable as part of the variable name.

```
% Auto-generated by MATLAB on 12-Apr-2024 17:11:34

%% Set up the Import Options and import the data
opts = spreadsheetImportOptions("NumVariables", 8);

% Specify sheet and range
opts.Sheet = "Data";
opts.DataRange = "A2:H3803";
```

```
%% Convert to output type
FuelTypeCode = tbl.FuelTypeCode;
StationName = tbl.StationName;
StreetAddress = tbl.StreetAddress;
IntersectionDirections = tbl.IntersectionDirections;
City = tbl.City;
State = tbl.State;
Latitude = tbl.Latitude;
Longitude = tbl.Longitude;
```

Figure 2. Matlab code to read the data in vector form (independent vectors for each column).

b) Add code the Matlab script created in part (a) to extract all electric charging stations (designated as ELEC in the fuel type code. Provide a list of the first 15 station names so that I can verify that the code works.

```
% Part (b) get the electric stations

matchElectric            = strcmp(FuelTypeCode,'ELEC');
indicesElectricStations = find(matchElectric);   % Indices of the
electricStationNames = StationName(indicesElectricStations);
```

```
{'City of LA Lot 715'            }
{'Schoharie Elementary School'  }
{'Juniper Hotel and Bistro'     }
{'Miller Honey Farms'           }
{'The Rockaway Hotel'           }
{'Forbes Garage'                }
{'Claire Pointe'                }
{'Vernon Area Public Library'   }
{'Oberlin Elementary School'    }
{'Harbor Springs'               }
{'Hale'                         }
{'Jackson Airport'              }
{'Central Lake - Village Market'}
{'Harrisville'                  }
{'South Haven'                  }
```

Figure 3. Matlab code to extract the electric stations. The bottom section shows the first 15 electric stations.

c) Use the US map provided in assignment 7 to plot the locations of the electric charging stations. Label them with a red marker.

```matlab
% Part (c) get a US map and plot the electric stations
% Load the US map provided in class
load usamap

% Make a plot and hold the plot

plot(uslon,uslat)
xlabel("Longitude (deg.)")
ylabel("Latitude (deg.)")
hold on

% Obtain the latitude and longitudes of each electric stations

longitudeElectricStation = Longitude(indicesElectricStations);
latitudeElectricStation    = Latitude(indicesElectricStations);

plot(longitudeElectricStation,latitudeElectricStation,'+r')
```

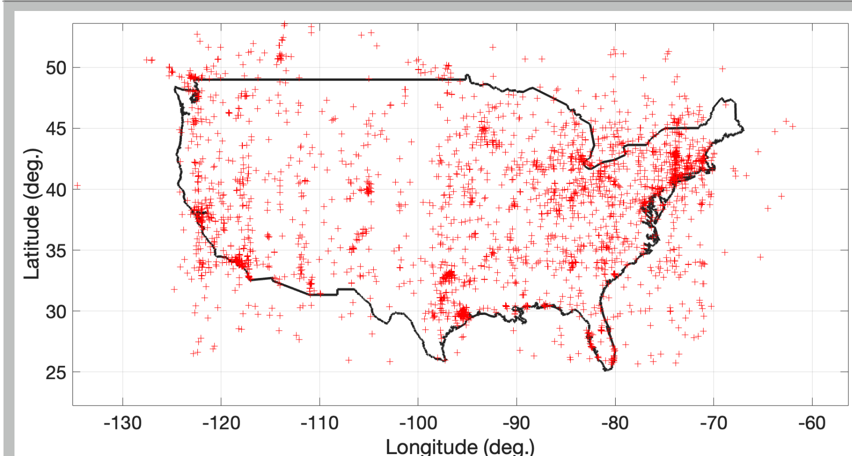


Figure 4. Matlab code to plot the US map. The data was extracted from an EPA database. It is clear that many stations do not have the correct latitude and longitude coordinates. I used a red + marker instead.

d) Add code to item (b) to calculate the number of CNG stations in the data. The calculation should be done in code. Display the answer in the Command window.

```
67    % Part (d) get CNG stations
68
69    matchCNG              = strcmp(FuelTypeCode,'CNG');
70    indicesCNGStations    = find(matchCNG);   % Indices of the electric stations
71    countCNGStations      = length(indicesCNGStations );
72
73    % Display the number of CNG stations
74    clc
75    disp(['Number of CNG Stations =  ',num2str(countCNGStations)])
```

```
Command Window
Number of CNG Stations =  65
fx >>
```

Figure 5. Matlab code to calculate the number of CNG stations.

e) Add code to item (b) to calculate the number of electric stations in the state of New York. The calculation should be done in code. Display the answer in the Command window.

```
77    % Part (e) get the electric stations in the state of New York
78
79    matchElectricNY              = strcmp(FuelTypeCode,'ELEC') & strcmp(State,'NY');
80    indicesElectricStationsNY    = find(matchElectricNY);   % Indices of the electric stations in NY
81    countElectricNYStations      = length(indicesElectricStationsNY);
82
83    % Display the number of CNG stations
84    clc
85    disp(['Number of Electric Stations in New York =  ',num2str(countElectricNYStations)])
```

```
Command Window
Number of Electric Stations in New York =  173
fx >>
```

Figure 6. Matlab code to calculate the number of stations in New York. Note that I used a combination of the strcmp command and the & command in Matlab (& = AND) in line 70 of the code.

Problem 2 (40 points)

The Manning equation is an empirical relationship used by civil engineers to estimate the flow characteristics inside pipes and channels. Figure 7 shows a simple rectangular channel.

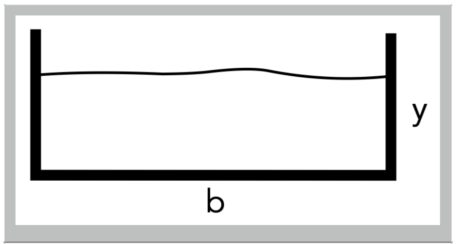


Figure 7. Simple Rectangular Channel.

For a rectangular channel, the following formulas apply.

$A = by$ % Area of the flow (ft^2)

$P = b + 2y$ % Wetted perimeter (ft)

$R = \dfrac{by}{b + 2y}$ % Hydraulic radius (ft)

The hydraulic radius, R is the quotient of the cross sectional area to the wetted perimeter, $R = A/P$.

The basic Manning Equation is:

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

Where:

Q is the discharge (cu. feet per second)

R is the hydraulic radius in feet (area of section / wetted perimeter)

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

A is the cross-sectional area of the flow (ft^2)

n is the pipe roughness coefficient (see table below).

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

a) Create a Matlab script to estimate the values of *A, P, and R* given the dimensions of b and y (in Figure 2). Test the code with values of *b*=30 feet and *y*=6 feet.

```
if strcmp(material,'Concrete')
    roughness = 0.012;
elseif strcmp(material,'Metal')
   roughness = 0.023;
end

%
b = 15:1:30;   % base of the open channel (ft)
y = 6;            % height of channel (ft)

% Calculate the area exposed, wetted perimeter
% and hydraulic radius
Area            = b .* y;         % area in square feet
Perimeter       = b + 2*y;       % wetted perimeter (feet)
Radius           = Area ./ Perimeter;         % Hydraulic radius (feet)
```

Figure 8. Code to estimate the area, wetted perimeter and hydraulic radius.

b) Add code to part (a) to estimate Q (discharge) using the Manning equation given all four parameters (A, R, S and n). Test the script for a concrete rectangular channel with the following parameters: S=0.002 ft/ft.

```
% Formula to  calculate the discharge

Q = ( ( 1.486 * Area .* ( Radius  .^(2/3) ) .* ( slope .^(1/2) ) ) ) ./ (roughness);

plot(Radius,Q,'o-b')
xlabel('Hydraulic Radius (ft^2)')
ylabel('Discharge (cu. feet/second)')
grid
```

```
Command Window
Discharge (cu. feet/second)  =  2630.1098
fx >>
```

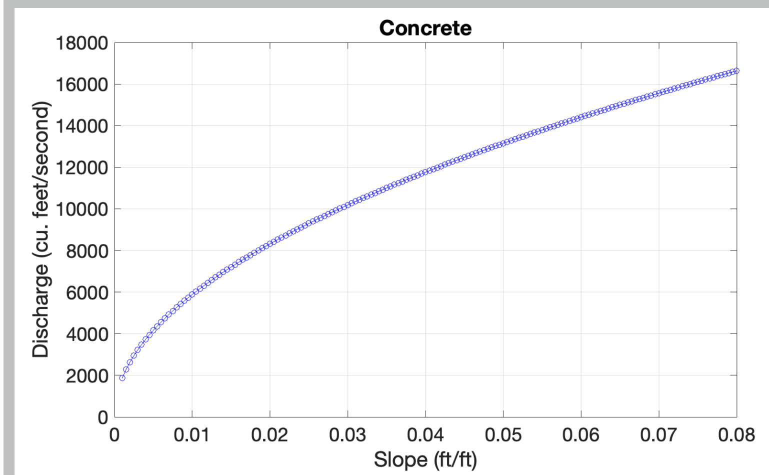
Figure 9. Code to estimate the discharge (Q).

c)

c) Add code to (a) to estimate the discharge (Q) for values of slope ranging from 0.001 to 0.008 (ft/ft).

```
% Define the material of the open channel
material = 'Concrete';

% Script to find the Discharge given the hydraulic radius, slope,
% cross sectional area and roughness.

slope = 0.001:0.0005:0.08;
```

```
% Formula to  calculate the discharge

Q = ( ( 1.486 * Area .* ( Radius  .^(2/3) ) .* ( slope .^(1/2) ) ) ) ./ (roughness);

plot(slope,Q,'o-b')
title(material)
xlabel('Slope (ft/ft)')
ylabel('Discharge (cu. feet/second)')
grid
```



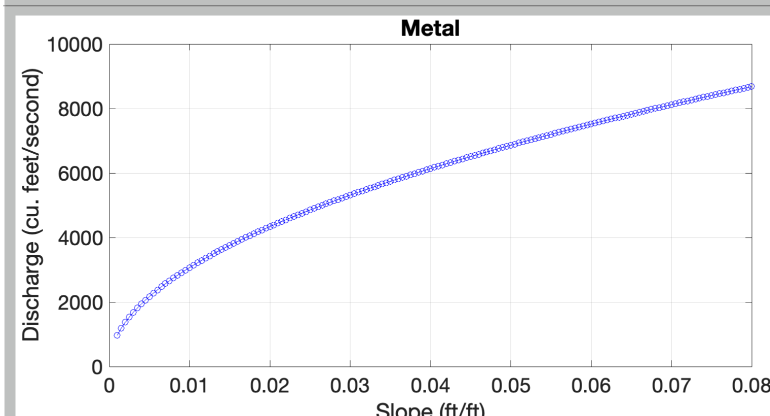


Figure 10. Code to estimate the discharge (Q) for various slopes.

D) In a single graph, plot the values of discharge (Q) for various slopes.

Problem 3 (30 points)

An engineer formulates a linear programming problem to estimate the number of tons to be produced of two types of concrete mixtures. Figure 11 shows the initial sketch showing a delivery constraint and a production constraint. Both concrete mixes are manufactured with the same equipment. The standard concrete sells for $1,560 per ton. The premium concrete sells for $1,635 per ton.

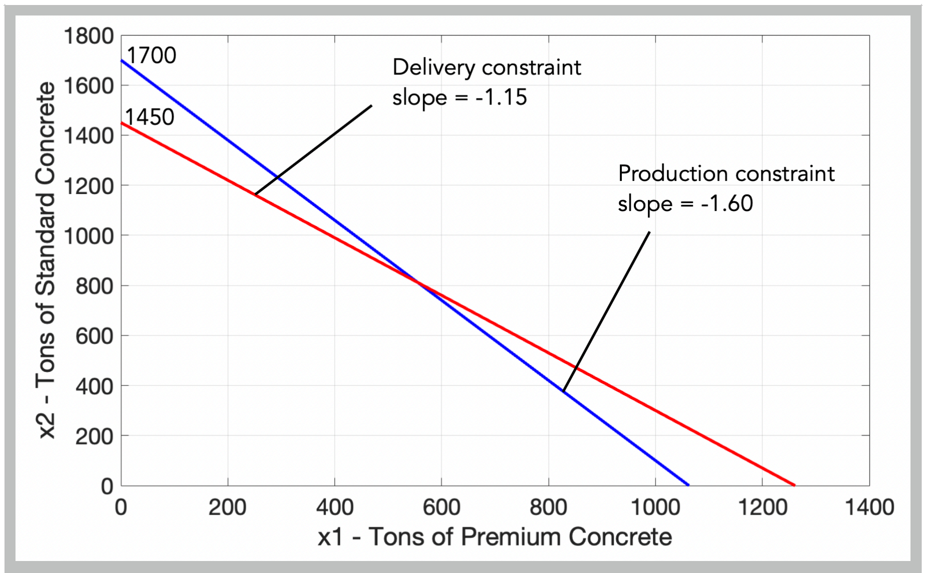


Figure 11. Graphical Representation of Concrete Production and Distribution.

a) Write the equations of the linear programming problem. Assume the company wants to maximize the revenue for the company.

Equations:

Maximize $Z = 1635x_1 + 1560x_2$

Subject to:

$1.6x_1 + x_2 <= 1700$

$1.15x_1 + x_2 <= 1450$

$x_1, x_2 >= 0$

b) Solve the problem using Excel Solver. Tell me how many tons of each concrete type should be produced to maximize the profit.

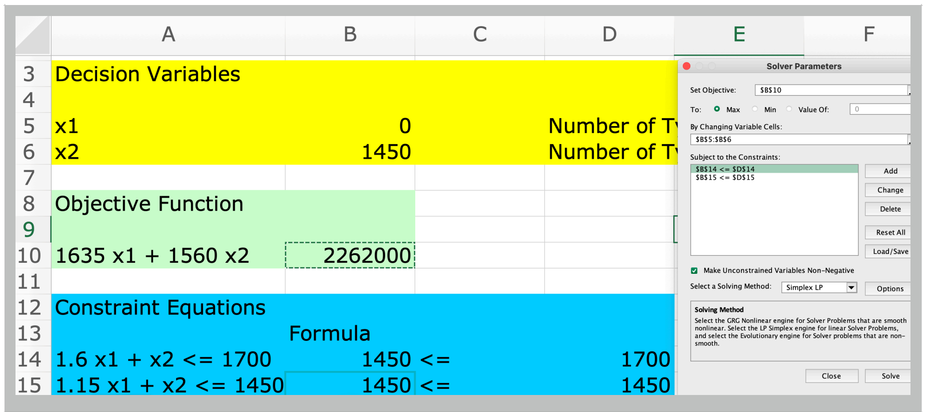


Figure 12. Excel Solver Solution. The optimal solution is x1=1450 and x2=0. The Objective function is Z=$2,262,000.

c) Solve the problem by hand using the Simplex Method. Clearly show your tables and indicate which variables are the basic variables in the current solution.

Adjust the constraint equations by adding one slice variable for each constraint equations.

Max $Z - 1635x_1 - 1560x_2 = 0$

$1.6x_1 + x_2 + x_3 = 1700$

$1.15x_1 + x_2 + x_4 = 1450$

$x_1, x_2, x_3, x_4 > = 0$

Table. Initial Tableau to Solve the Problem.

BV	Z	X1	x2	X3	X4	RHS
Z	1	-1635	-1560	0	0	0
X3	0	1.6	1	1	0	1700
X4	0	1.15	1	0	1	1450

The basic variables are x3, and x4. Non-basic variables are X1 and X2. Current solution for Z = 0.

BV	Z	X1	x2	X3	X4	RHS	Ratio
Z	1	-1635	-1560	0	0	1	
X3	0	1.6	1	1	0	1700	1062.5
X4	0	1.15	1	0	1	1450	1260.9

Step 2: Select pivot column (column with coefficient for X1 - in yellow).

Step 3: Select the pivot row as the one with the smallest ratio of RHS and picot column coefficients (row in yellow)

Step 4: Perform row operations to zero all elements of pivot column.

BV	Z	X1	x2	X3	X4	RHS	Ratio
Z	1	-1635	-1560	0	0	1	
X3	0	1.0	0.625	0.625	0	1062.50000(	1062.5
X4	0	1.15	1	0	1	1450	1260.9

Second Tableau.

BV	Z	X1	x2	X3	X4	RHS
Z	1	0	-538.125	1021.875	0	1737188.5
X1	0	1	0.625	0.625	0	1062.5
X4	0	0	0.28125	-0.71875	1	228.125

Z=$1737188.5, x1 = 1062.5 and x4=228.125, X3 and x2 are zero.

Perform the ratio test to determine the pivot row.

BV	Z	X1	x2	X3	X4	RHS	Ratio
Z	1	0	-538.125	1021.875	0	1737188.5	
X1	0	1	0.625	0.625	0	1062.5	1700
X4	0	0	0.28125	-0.71875	1	228.125	811.11

Row operations on row 3.

BV	Z	X1	x2	X3	X4	RHS
Z	1	0	-538.13	1021.88	0.00	1737188.50
X1	0	1	0.63	0.63	0.00	1062.50
X4	0	0	1.00	-2.56	3.56	811.11

Third Tableau

BV	Z	X1	x2	X3	X4	RHS
Z	1.00	0.00	0.13	-353.65	1913.78	2173769.06
X1	0.00	1.00	0.00	2.22	-2.22	555.56
X2	0.00	0.00	1.00	-2.56	3.56	811.11

Z=$2173769, x1 = 555.6 and x2=811.1. X3 and x4 are zero.

The solution in the third tableau is not optimal. Coefficient of x3 is still negative so the solution can be improved. Introduce variable x3 into the solution and improve Z to reach optimality. The current solution of the third tableau is the intersection of the two constraint equation lines (see Figure 3).

Perform ratio test to determine the pivot row.

BV	Z	X1	x2	X3	X4	RHS	Ratio
Z	1.00	0.00	0.13	-353.65	1913.78	2173769.06	
X1	0.00	1.00	0.00	2.22	-2.22	555.56	250.00
X2	0.00	0.00	1.00	-2.56	3.56	811.11	-317.39

Take the lowest non-negative number of the ratio tests. X3 enters the BV set. X1 leaves the solution.

Fourth Tableau.

BV	Z	X1	x2	X3	X4	RHS
Z	1.000	159.1	0.1	0.0	1,560.2	2,262,183.3
X3	0.000	0.5	0.0	1.0	-1.0	250.0
X2	0.000	1.2	1.0	-0.0	1.0	1,450.1

Solution in the fourth tableau is optimal. All Coefficients in the Z-row are positive or zero.

Z=$2,262,183, x1 = 0 and x2=1450. x3=250 and x4 = 0.

Note: slack variables (x3 or x4) can be positive in the optimal solution.

The progression of each solution is shown in Figure 13.

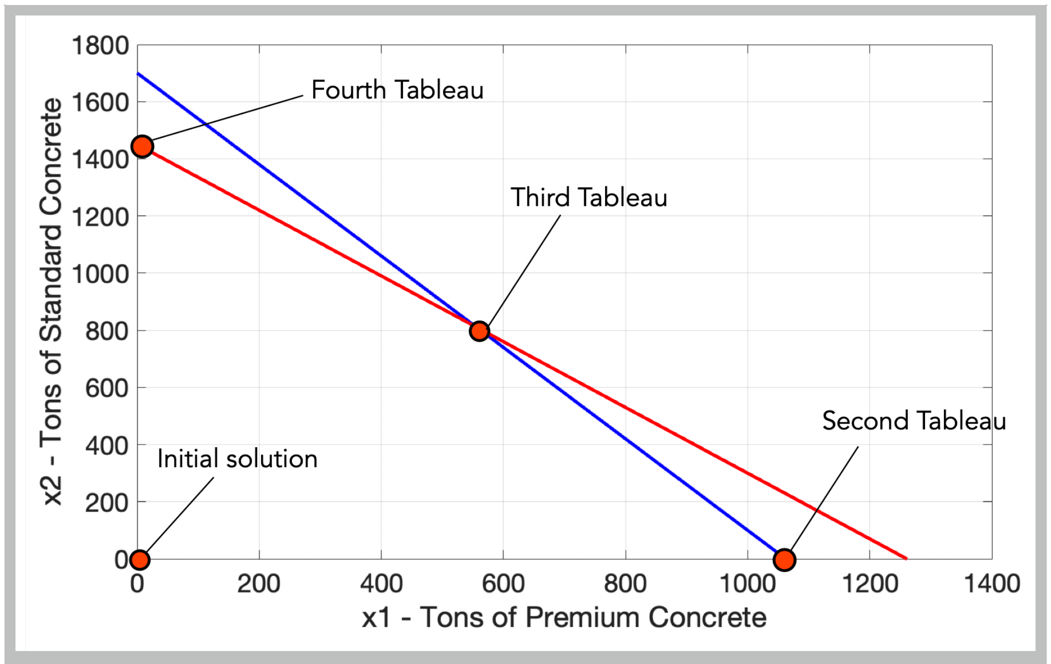


Figure 13. Simplex Method solution. The optimal solution is x1=1450 and x2=0. The Objective function is Z=$2,262,000.