CEE 3804 Exam2 (Spring 2026)

Computer Applications in Civil Engineering

Solution

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 VBA/MATLAB 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 acceptable font size 10.

Problem 1 (30 points)

Civil engineering undergraduate students collected airport noise data in the summer of 2015 as part of a study abroad program (see Figure 1). Airport noise is important to mitigate environmental impacts around airports.

Figure 1. Virginia Tech students collecting airport noise data at the Punta Cana International Airport. A second group of students collected noise levels at the airport ramp. That data is provided to you.

The noise level data collected was recorded as a function of time (see Figure below). A data file with the data collected is provided. The information in the file includes the time of day of the recording (in decimal hours) and the A-weighted equivalent continuous sound level (Called Noise level) in decibels - a measure of the noise produced by the aircraft. A screen capture of the data provided is shown below.

	A	B	C
1	Day	Time of Day (hrs)	Noise Level (dBA)
2	1	5.5067	48.1
3	1	5.5069	51.01
4	1	5.5072	52.43
5	1	5.5075	51.54
6	1	5.5078	51.01

Figure 2. Noise Data Collected at the Ramp at Punta Cana Airport by Virginia Tech Students.

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

```
%% Import data from spreadsheet
% Script for importing data from the following spreadsh
%
%    Workbook: /Users/vuela/Courses/CEE 3804/CEE 3804 S
%    Worksheet: Sheet1

clear all
close all
%
% Auto-generated by MATLAB on 02-May-2026 13:54:27

%% Set up the Import Options and import the data
opts = spreadsheetImportOptions("NumVariables", 3);
```

```
% Specify sheet and range
opts.Sheet = "Sheet1";
opts.DataRange = "A2:C91551";

% Specify column names and types
opts.VariableNames = ["Day", "TimeOfDay_hrs_", "NoiseLe
opts.VariableTypes = ["double", "double", "double"];

% Import the data
AirportNoiseData3 = readtable("/Users/vuela/Courses/CEE

%% Convert to output type
Day = AirportNoiseData3.Day;
TimeOfDay_hrs = AirportNoiseData3.TimeOfDay_hrs_;
NoiseLevel_dBA = AirportNoiseData3.NoiseLevel_dBA_;

%% Clear temporary variables
clear AirportNoiseData3 opts
```

Figure 2.1 Matlab Code to read Noise Data. The Code was Auto-Generated. Three Vectors ar Produced with Day, Time of Day, and Noise Level Information.

b) Add code to the Matlab script created in part (a) to plot the noise levels (as a function of time) recorded by the students. Use the subplot command to partition the figure into two plots. One for Day 1 and one for Day 2. Comment on the observed patterns. The time is in the x-axis. Noise level is on the y-axis.

```
% Find the indices of the observations for days 1 and 2

indicesDay1 = find(Day==1);
indicesDay2 = find(Day==2);

% Retrieve  the data for days 1 and 2 and
% save into new vectors

TimeOfDay1_hrs = TimeOfDay_hrs(indicesDay1);
TimeOfDay2_hrs = TimeOfDay_hrs(indicesDay2);

NoiseLevelDay1_dBA = NoiseLevel_dBA(indicesDay1);
NoiseLevelDay2_dBA = NoiseLevel_dBA(indicesDay2);
```

```
figure
subplot(2,1,1)
plot(TimeOfDay1_hrs,NoiseLevelDay1_dBA,'+r',MarkerSize=2
xlabel('Time of Day (hrs)')
ylabel('Noise Level (dBA)')
title("Noise Data for Day 1")
grid

subplot(2,1,2)
plot(TimeOfDay2_hrs,NoiseLevelDay2_dBA,'^b',MarkerSize=2
xlabel('Time of Day (hrs)')
ylabel('Noise Level (dBA)')
title("Noise Data for Day 2")
```

Figure 2.1 Matlab Code to Parse the Noise Data by Day.

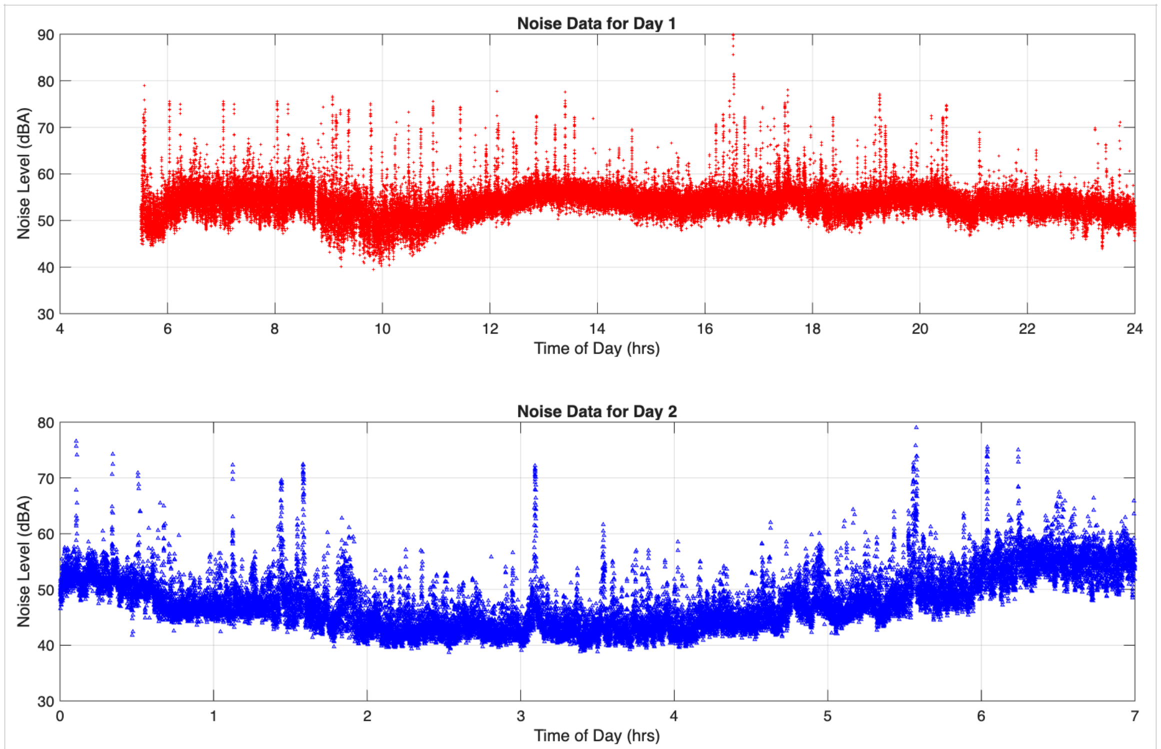

Figure 2.2 Noise Data for Days 1 and 2.

c) Calculate the mean and the standard deviation of the Noise Level values recorded by the instrument on **Day 1**.

```
% Find the average and standard deviation of Noise Level data for Day 1

meanNoiseLevel_Day1_dBA = mean(NoiseLevelDay1_dBA);
stdNoiseLevel_Day1_dBA = std(NoiseLevelDay1_dBA);
disp(['Average Noise Level (dBA)  ', num2str(meanNoiseLevel_Day1_dBA)]);
disp(['Std. Deviation of Noise Level (dBA)  ', num2str(stdNoiseLevel_Day1
```

Average Noise Level is 53.89 dBA. The Standard Deviation of the Noise Level for Day 1 is Std. Deviation of Noise Level 3.32 (dBA).

Figure 2.3 Calculation of Mean and Standard Deviation of Noise Levels for Day 1.

d) Create a histogram of the Noise Levels recorded on Day 1. What kind of distribution do you see at the airport ramp noise levels?

```
% Do a histogram of the noise levels

% Create a histogram of the Noise Levels for Day 1
figure
histogram(NoiseLevelDay1_dBA, 'FaceColor', 'r', 'EdgeCo
xlabel('Noise Level (dBA)');
ylabel('Frequency');
title('Histogram of Noise Levels for Day 1');
grid on;
```

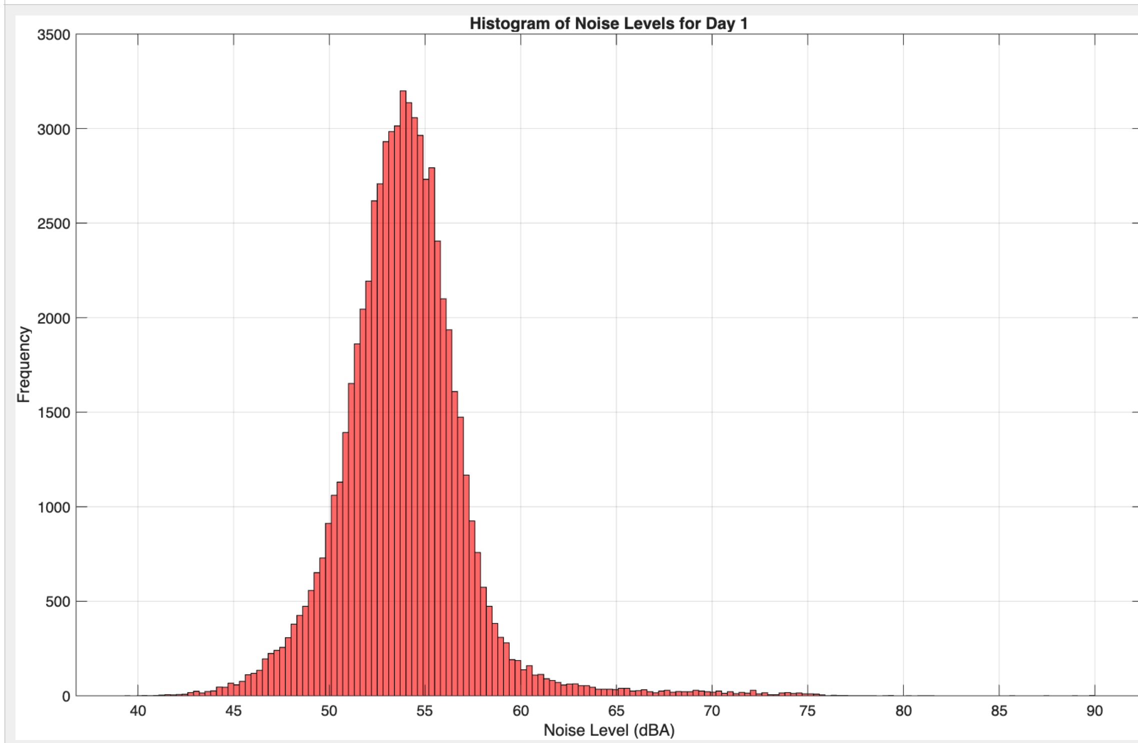

Figure 2.4 Histogram of Noise Levels for Day 1.

The histogram reveals a Gaussian distribution (also called normal distribution).

e) Find the number of times (in Day 1) when the noise level exceeds 65 dBA. Estimate the total time people working at the ramp may be exposed to 65 dBA or higher.

```
% Find the number of times the noise level is above
% 65 dBA

readingsAbove65_dBA = sum(NoiseLevelDay1_dBA > 65);     % Matlab Copilot
disp(['Number of times noise level exceeds 65 dBA: ', num2str(readingsAbove65_dBA)]);

% Make a cummulative density function of the data
cdfplot(NoiseLevelDay1_dBA)
xlabel('Noise Level (dBA)');
ylabel('Cummulative Density Function (dim)');
title('CDF Noise Levels for Day 1');
grid on;
```

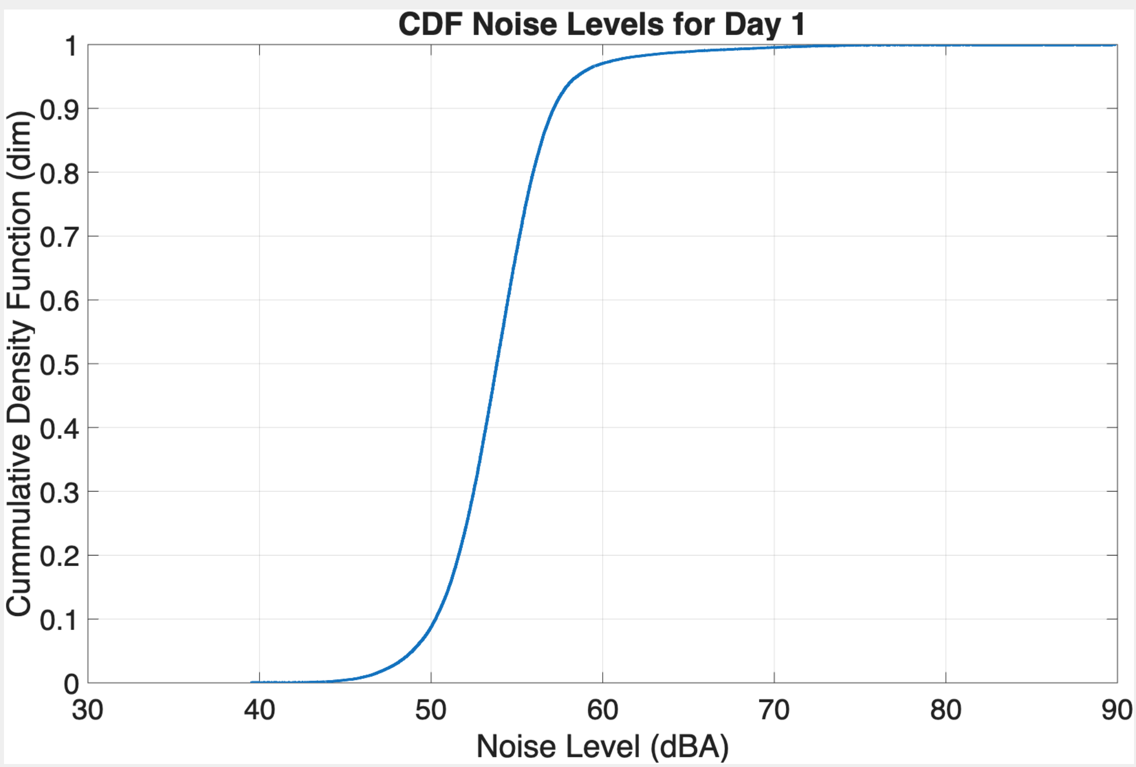

Figure 2.5 Code to Find the Number of Times Noise Levels Exceed 65 dBA. The Plot shows a Cumulative Density Function of the Distribution of Noise Levels.

The average sampling rate of the noise data is 2.7872e-04 seconds. The number of instances found to be above 65 dBA is **738 events (noise readings)**. Figure 2.5 shows that a small percent of noise level events exceed 65 dBA. The CDF plot shows that 98.9% of the noise events are below 65 dBA.

Problem 2 (35 points)

The ACME company makes a \$1050 profit on every metric ton of high-strength concrete mix produced and delivered. The company makes \$980 on every metric ton of standard-strength concrete mix produced and delivered. After formulating the problem as an optimization problem to maximize the revenue for the ACME company, the engineers produce the following **constraint equations** that account for production and delivery constraints.

$x_1 + x_2 <= 545$

$x_1 + 1.6x_2 <= 800$

$1.4x_1 + x_2 <= 705$

$x_1, x_2 >= 0$

Where:

x_1 is the amount of high-strength concrete produced and delivered

x_2 is the amount of standard-strength concrete produced and delivered

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

b) Plot the constraint equations using Matlab. Show me you Matlab code and the plot. Label the three constraint equations and label using the legend in the plot.

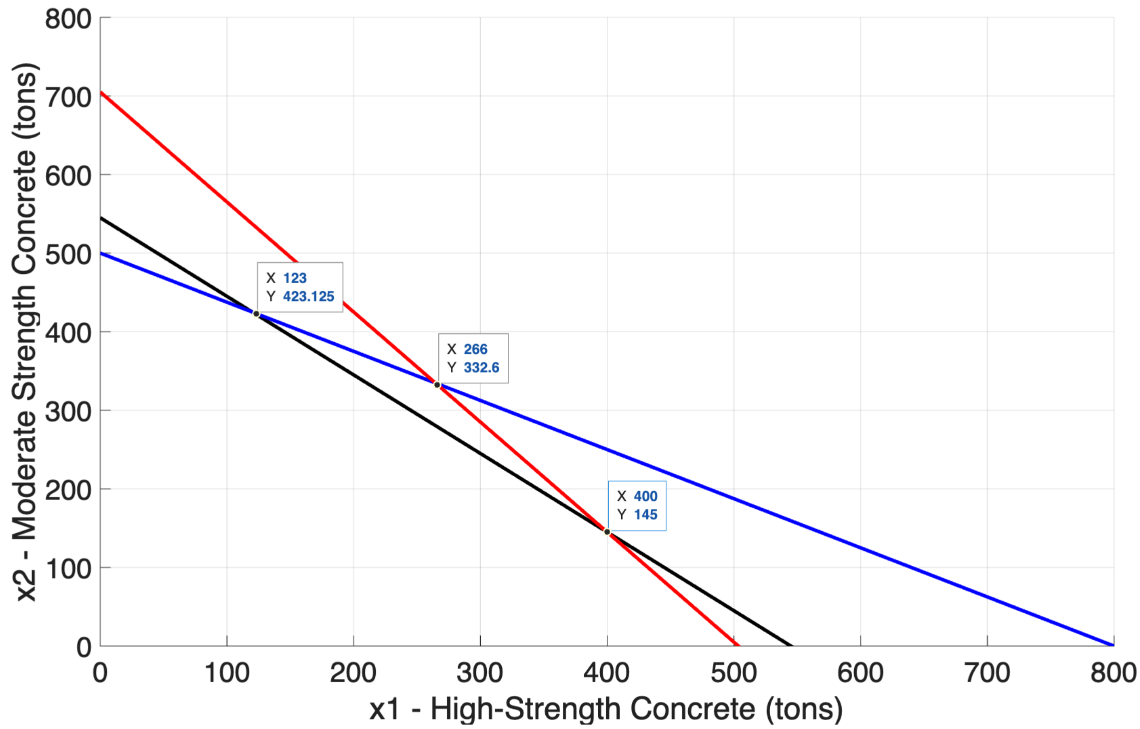

Figure 3. Concrete Linear Programming Problem.

c) Find the optimal solution to the problem by hand using the Simplex Method (tables and row operations) explained in class. Indicate the numerical values of all decision variables in every table. Indicate the value of the objective function Z in every table. This task requires calculations and row operations and you need to show me your row operations clearly.

All constraints are of the type <=. To solve the problem use three slack variables.

Maximize $Z - 1050x_1 - 980x_2 = 0$

Subject to the following equations:

$x_1 + x_2 + x_3 = 545$

$x_1 + 1.6x_2 + x_4 = 800$

$1.4x_1 + x_2 + x_5 = 705$

$x_1, x_2 >= 0$

Tableau # 1. Problem is in standard form (canonical form).

BV	Z	x_1	x_2	x_3	x_4	x_5	RHS
Z	1	-1050	-980	0	0	0	0
x_3	0	1	1	1	0	0	545
x_4	0	1.0	1.6	0	1	0	800
x_5	0	1.4	1	0	0	1	705

Tableau # 1 Selection of Pivot Column and pivot row.

BV	Z	x_1	x_2	x_3	x_4	x_5	RHS	Ratio Test
Z	1	-1050	-980	0	0	0	0	
x_3	0	1	1	1	0	0	545	545
x_4	0	1.0	1.6	0	1	0	800	800
x_5	0	1.4	1	0	0	1	705	503.6

$x_2 = 0$ and $x_1 = 0$

$x_3 = 545$ metric tons

$x_4 = 800$ metric tons

$x_5 = 705$ metric tons

$Z = \$0$

In the next tableau, x_1 enters the Basic Variable set and x_5 leaves the solution (becomes zero).

Suggested row operations:

1) Divide row with BV x_5 (third constraint equation) by 1.4

2) Multiply the third constrain equation by 1050 and add to the Zrow.

3) Multiply the third constrain equation by -1 and add to the first constraint equation.

4) Multiply the third constrain equation by -1 and add to the second constraint equation.

Tableau # 2 with Pivot Column and Pivot Row Selected.

BV	Z	x_1	x_2	x_3	x_4	x_5	RHS	Ratio Test
Z	1.00	0.00	-230.00	0.00	0.00	750.00	528750.0(	
x_3	0.00	0.00	0.29	1.00	0.00	-0.71	41.43	145.00
x_4	0.00	0.00	0.89	0.00	1.00	-0.71	296.43	334.68
x_1	0.00	1.00	0.71	0.00	0.00	0.71	503.57	705.00

In the next tableau, x_2 enters the Basic Variable set and x_3 leaves the solution (becomes zero).

In the second tableau, the values of the decision variables are:

x_1 = 503.6 metric tons of high-strength concrete

$x_2 = 0$ and $x_5 = 0$

x_3 = 145 metric tons

x_4 = 296.4 metric tons

Z = $528,750

Tableau # 3 The table is the optimal solution. No negative coefficients left in the Z-row.

BV	Z	x_1	x_2	x_3	x_4	x_5	RHS
Z	1.00	0.00	0.00	805.00	0.00	175.00	562,100
x_2	0.00	0.00	1.00	3.50	0.00	-2.50	145
x_4	0.00	0.00	0.00	-3.10	1.00	1.50	168
x_1	0.00	1.00	0.00	-2.50	0.00	2.50	400

The values of the decision variables in the optimal solution are:

x_1 **= 400 metric tons of high-strength concrete**

x_2 **= 145 metric tons of standard concrete**

Z **= $562,100**

d) Solve the problem using Excel Solver. Verify the solution obtained in part (c).

Decision Variables			
x1	400		Concrete 1
x2	145		Concrete 2
Objective Function			
1050 x1 + 980 x2	562100		
Constraint Equations			
	Formula		
x1 + x2 <= 545	545	<=	545
x1+ 1.6 <= 800	632	<=	800
1.4 x1 + x2 <= 705	705	<=	705

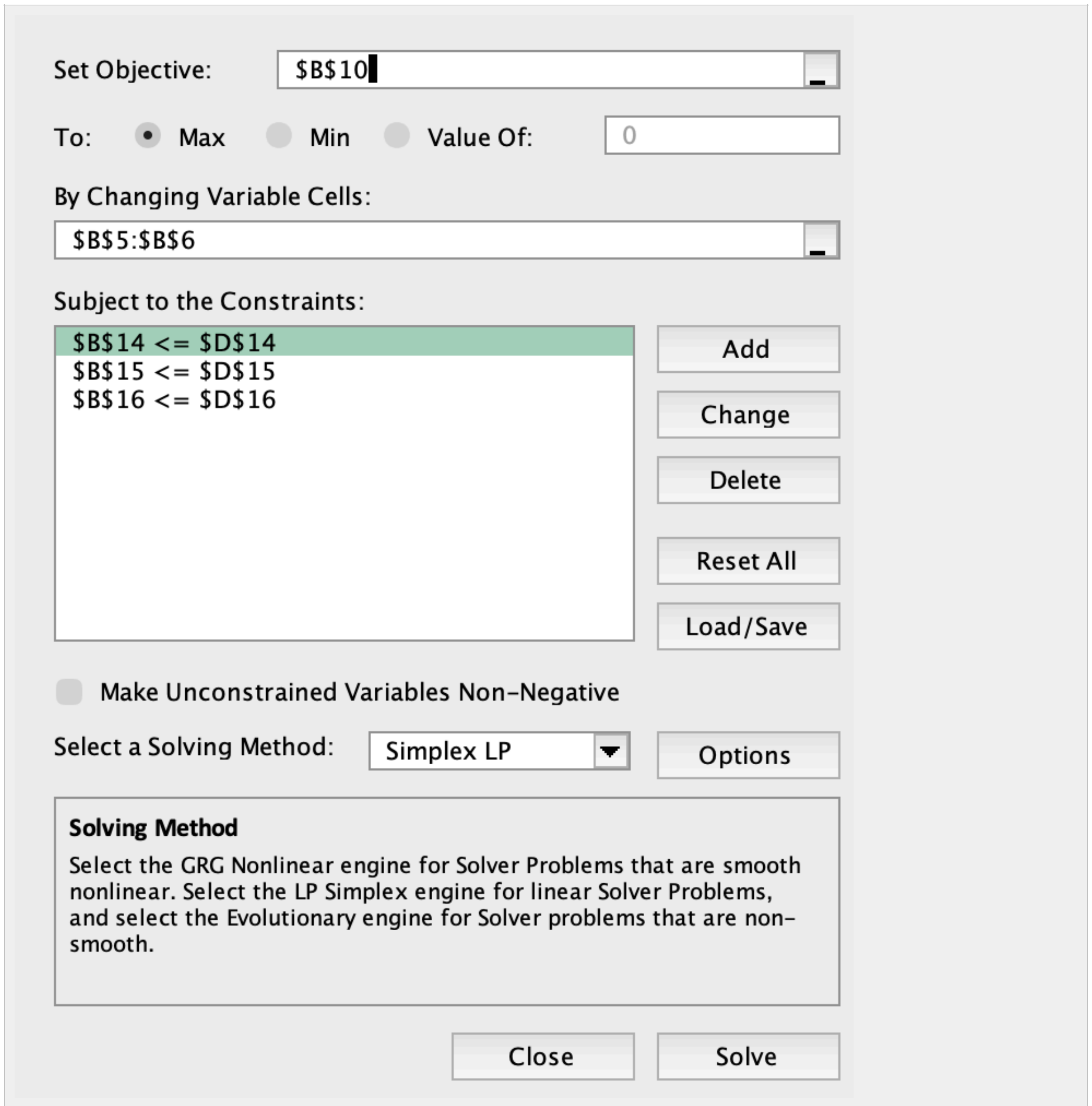

Figure 3.1 Excel Solver Solution.

The optimal solution is to produce 400 metric tons of high-strength concrete and 165 of the standard-strength concrete. The total profit is $562,100.

The Excel Solver solution validates both the graphical solution and the solution obtained using the Simplex Method.

Problem 3 (35 points)

A civil engineering company performs an experiment to predict the productivity of a new 0.75 cubic meter bucket capacity excavator. Figure 4 shows measured cycle times for the excavator. The excavator cycle time includes four phases: digging, swinging (loaded), dumping, and swinging (unloaded) back to digging position.

Measurement	Cycle Time (seconds)
1	30.4
2	30.9
3	28.7
4	28.3
5	32.8
6	33.9
7	30
8	34.2

Figure 4. Sample Excavator Cycle Times Measured at a Construction Site.

The basic equation to estimate the productivity (called production rate - P_R) of the excavator is:

$$P_R = \frac{3600 * C_B * E_f}{T_{cycle}}$$

Where:

P_R is the production rate of the excavator (cubic meters/hr)

C_B is the bucket capacity of the excavator (cubic meters)

E_f is the efficiency factor of the excavation process (dimensionless)

T_{cycle} is the excavator cycle (in seconds)

The formula to estimate the cost of the excavator is:

$$C_{vol} = \frac{P_R}{C_{hr}}$$

P_R is the production rate of the excavator (cubic meters/hr)

C_{vol} is the unit cost of moving material with the excavator ($/cu. Meter)

C_{hr} is the cost per hour to use the excavator ($/hr)

a) Create a **function in Matlab** to estimate the production rate (P_R) and the unit cost of moving material (C_{vol}) with the excavator as a function of parameters C_B, E_f, T_{cycle}, and C_{hr}. Your function produces two outputs and accepts four inputs.

```
function [productionRate,costOfExcavator]=excavatorMetrics(bucketCapacity...
    ,effExcavator,excavatorCycle,unitCost)

% Function to estimate the production rate and the cost
% of using a bucket excavator

 % productionRate is the production rate of the excavator (cubic meters/hr)
 % bucketCapacity is the bucket capacity of the excavator (cubic meters)
 % effExcavator is the efficiency factor of the excavation process (dimensionless
 % excavatorCycle is the excavator cycle (in seconds)
 % unitCost is the unit cost of moving material with the excavator ($/cu.m)
 % costOfExcavator is the unit cost of moving material ($/cu.meter)

 % Calculate the production rate

 productionRate = 3600 * bucketCapacity * effExcavator ./ excavatorCycle;

 % Estimate the cost of the excavator based on the formula provided
 costOfExcavator = productionRate ./ unitCost ; % cost
```

Figure 5. Function to Estimate Production Rate and Cost of Using an Excavator.

b) Create a **separate Matlab script** to read the field data containing values of T_{cycle} provided in the Excel file. The Matlab script calls the function created in part (a) to estimate the production rate (P_R) associated with every measured cycle time T_{cycle} in the Excel file provided. The function also return the unit cost of moving material with the excavator. Ran the script that calls the function assuming an efficiency factor (E_f) of 0.86 and the excavator cost is $150/hour.

```
% Matlab script to to estimate the production rate and the cost
% of using a bucket excavator

clear
close all

 % productionRate is the production rate of the excavator (cubic meters/hr)
 % bucketCapacity is the bucket capacity of the excavator (cubic meters)
 % effExcavator is the efficiency factor of the excavation process (dimensionle
 % excavatorCycle is the excavator cycle (in seconds)
 % unitCost is the unit cost of moving material with the excavator ($/cu.m)
 % costOfExcavator is the unit cost of moving material ($/cu.meter)

 % Read the data from an Excel file

 %% Import data from spreadsheet
% Script for importing data from the following spreadsheet:
%
%    Workbook: /Users/vuela/Courses/CEE 3804/CEE 3804 Spring 2026/Exams /excava
%    Worksheet: Excavator Data
```

```
%% Set up the Import Options and import the data
opts = spreadsheetImportOptions("NumVariables", 2);

% Specify sheet and range
opts.Sheet = "Excavator Data";
opts.DataRange = "A2:B688";

% Specify column names and types
opts.VariableNames = ["Measurement", "CycleTime_seconds"];
opts.VariableTypes = ["double", "double"];

% Import the data
excavator_cycleTime_data = readtable("/Users/vuela/Courses/CEE 3804/CEE 3804 Sp

%% Convert to output type
Measurement = excavator_cycleTime_data.Measurement;
excavatorCycle = excavator_cycleTime_data.CycleTime_seconds;

%% Clear temporary variables
clear excavator_cycleTime_data opts
```

```
 % Define the parameters to estimate production rate and cost of excavator

 bucketCapacity = 0.75;     % cubic meters
 effExcavator = 0.86;       % dim
 unitCost = 150;            % ($/cu.meter)
 % costOfExcavator is the unit cost of moving material ($/cu.meter)

 % Calculate the production rate

[productionRate,costOfExcavator]= excavatorMetrics(bucketCapacity...
    ,effExcavator,excavatorCycle,unitCost);

% Make a plot of production rate versus cost

figure
plot(productionRate,costOfExcavator,'or')
ylabel('Cost of Using Excavator ($/cu.meter)')
xlabel('Production Rate (cubic meters/hr)')
grid

```

Figure 5.1 Matlab Script to Call the Function to predict Excavator Metrics.

c) Add code to the Matlab script created in (b) to plot the excavator cycle (x-axis) versus production rate (y-axis). Use Marker Size 10 and blue circular markers in the plot.

```
% Make another plot (Production rate versus cycle time)

figure
plot(excavatorCycle,productionRate,'ob','MarkerSize',10)
xlabel('Excavator Cycle Time (seconds)','FontSize',10)
ylabel('Production Rate (cubic meters/hr)','FontSize',10)
grid

```

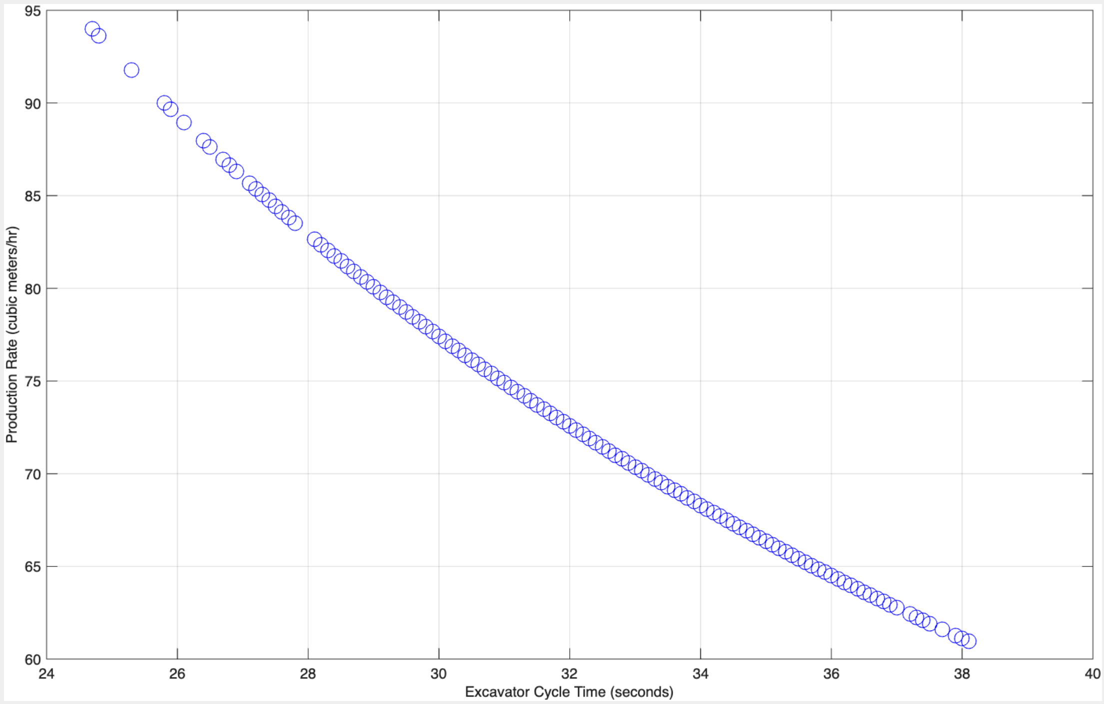

Figure 5.2 Matlab Script to Call the Function to predict Excavator Metrics.

d) Add more code to the Matlab script and perform a polynomial fit of the data (as plotted in part c) using a second order polynomial in Matlab. Display the polynomial coefficients in the Command Window.

```
% Find a polynomial of degree 2 (Production rate versus cycle time)

coeff = polyfit(excavatorCycle,productionRate,2);
disp(['The Coefficients of 2nd Order Polynomial are  ',num2str(coeff)])
```

```
The Coefficients of 2nd Order Polynomial are
0.07421395      -7.055113         222.32
```

Figure 5.3 Matlab Script to Perform the Least-Square, Polynomial Regression Analysis.