# Project One

## MAT350: Applied Linear Algebra

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# Problem 1

**Develop a system of linear equations for the network** by writing an equation for each router (A, B, C, D, and E). Make sure to write your final answer as A**x**=**b** where A is the 5x5 coefficient matrix, **x** is the 5x1 vector of unknowns, and **b** is a 5x1 vector of constants.

### Solution:

*Put your math/explanation here...*

*We are working with the pressumption that total incoming and transmitted data at each point is equal.*

*At point A 100 is in coming and x_(1) and 2x_(2) are transmitted out therefore the equation is x_(1)+2x_(2)=100*

*At point B x_(1) and x_(2) are incoming while x_(3) and x_(5) are transmitted out therefore the equation is x_(5)+x_(3) -x_(1)-x_(2)=0 which we can rewrite as -x_(1)-x_(2)+x_(3)+x_(5)=0*

*At point C x_(2) and 50 are the incoming while x_(3) and x_(5) are transmitted out therefore the equation is x_(5)+x_(3)-x_(2)=50 which we can rewrite as -x_(2)+ x_(3)+x_(5)=50*

*At point D x_(4) and x_(5) are the incoming while x_(2) and 120 are transmitted out therefore the equation is x_(2) - x_(4)- x_(5)=-120*

*At point E x_(5) is the incoming while x_(4) is transmitted out therefore the equation is x_(5)-x_(4)=0*

*Given that we have five equations and five varaibles matrix A will be a 5 by 5 matrix while our constant matrix b will be a 5 by 1*

*A=[1,2,0,0,0;-1,-1,1,0,1;0,-1,1,0,1;0,1,0,-1,-1;0,0,0,1,-1]*

*b=[100;0;50;-120;0]*

*x=[x_(1);x_(2);x_(3); x_(4);x_(5)]*

*Ax=b*

*[1,2,0,0,0;-1,-1,1,0,1;0,-1,1,0,1;0,1,0,-1,-1;0,0,0,1,-1][x_(1);x_(2);x_(3); x_(4);x_(5)]=[100;0;50;-120;0]*

$$\begin{matrix} 1 & 2 & 0 & 0 & 0 \\ -1 & -1 & 1 & 0 & 1 \\ 0 & -1 & 1 & 0 & 1 \\ 0 & 1 & 0 & -1 & -1 \\ 0 & 0 & 0 & 1 & -1 \end{matrix} \times \begin{matrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{matrix} = \begin{matrix} 100 \\ 0 \\ 50 \\ -120 \\ 0 \end{matrix}$$

```
A=[1,2,0,0,0;-1,-1,1,0,1;0,-1,1,0,1;0,1,0,-1,-1;0,0,0,1,-1]
```

```
A = 5×5
     1     2     0     0     0
    -1    -1     1     0     1
     0    -1     1     0     1
     0     1     0    -1    -1
     0     0     0     1    -1
```

```
b=[100;0;50;-120;0]
```

```
b = 5×1
   100
     0
    50
  -120
     0
```

```
x=A\b
```

```
x = 5×1
   50.0000
   25.0000
    2.5000
   72.5000
   72.5000
```

# Problem 2

Use MATLAB to construct the augmented matrix [A **b**] and then perform row reduction using the rref() function. Write out your **reduced matrix and identify the free and basic variables of the system**.

### Solution:

```
%code
AugmA=[A b]
```

```
AugmA = 5×6
     1     2     0     0     0   100
    -1    -1     1     0     1     0
     0    -1     1     0     1    50
     0     1     0    -1    -1  -120
```

```
     0     0     0     1    -1     0
```

```
rref(AugmA)
```

```
ans = 5×6
    1.0000         0         0         0         0   50.0000
         0    1.0000         0         0         0   25.0000
         0         0    1.0000         0         0    2.5000
         0         0         0    1.0000         0   72.5000
         0         0         0         0    1.0000   72.5000
```

```
%allthough we know that it has no free varaibles if it did this is how we
%would find it
[numeqsA,numvarA]=size(A)
```

```
numeqsA = 5
numvarA = 5
```

```
NumfreevarA= numvarA-numeqsA
```

```
NumfreevarA = 0
```

# Problem 3

Use MATLAB to **compute the LU decomposition of A**, i.e., find A = LU. For this decomposition, find the transformed set of equations L**y** = **b**, where **y** = U**x**. Solve the system of equations L**y** = **b** for the unknown vector **y**.

### Solution:

```
%code
%since I haved used x as variable before I will use x1 this time
[L, U]=lu(A)
```

```
L = 5×5
    1.0000         0         0         0         0
   -1.0000    1.0000         0         0         0
         0   -1.0000    1.0000         0         0
         0    1.0000   -0.5000    1.0000         0
         0         0         0   -1.0000    1.0000
U = 5×5
     1     2     0     0     0
     0     1     1     0     1
     0     0     2     0     2
     0     0     0    -1    -1
     0     0     0     0    -2
```

```
y=L\b
```

```
y = 5×1
   100
   100
   150
  -145
  -145
```

```
x1=U\y
```

```
x1 = 5×1
   50.0000
   25.0000
    2.5000
   72.5000
   72.5000
```

# Problem 4

Use MATLAB to **compute the inverse** of U using the inv() function.

## Solution:

```
%code
Uinv=inv(U)
```

```
Uinv = 5×5
    1.0000   -2.0000    1.0000         0         0
         0    1.0000   -0.5000         0         0
         0         0    0.5000         0    0.5000
         0         0         0   -1.0000    0.5000
         0         0         0         0   -0.5000
```

# Problem 5

**Compute the solution to the original system of equations** by transforming **y** into **x**, i.e., compute **x** = inv(U)**y**.

## Solution:

```
%code
%since we have used x and x1 we will use x2 this time
x2=Uinv*y
```

```
x2 = 5×1
   50.0000
   25.0000
    2.5000
   72.5000
   72.5000
```

# Problem 6

**Check your answer for $x_1$ using Cramer's Rule.** Use MATLAB to compute the required determinants using the det() function.

## Solution:

```
%let x_1 be x11 to avoid confusing it code
A1=A
```

```
A1 = 5×5
     1     2     0     0     0
    -1    -1     1     0     1
     0    -1     1     0     1
     0     1     0    -1    -1
     0     0     0     1    -1
```

```
A2=A
```

```
A2 = 5×5
     1     2     0     0     0
    -1    -1     1     0     1
     0    -1     1     0     1
     0     1     0    -1    -1
     0     0     0     1    -1
```

```
A3=A
```

```
A3 = 5×5
     1     2     0     0     0
    -1    -1     1     0     1
     0    -1     1     0     1
     0     1     0    -1    -1
     0     0     0     1    -1
```

```
A4=A
```

```
A4 = 5×5
     1     2     0     0     0
    -1    -1     1     0     1
     0    -1     1     0     1
     0     1     0    -1    -1
     0     0     0     1    -1
```

```
A5=A
```

```
A5 = 5×5
     1     2     0     0     0
    -1    -1     1     0     1
     0    -1     1     0     1
     0     1     0    -1    -1
     0     0     0     1    -1
```

```
A1(:,1)=b
```

```
A1 = 5×5
   100     2     0     0     0
     0    -1     1     0     1
    50    -1     1     0     1
  -120     1     0    -1    -1
     0     0     0     1    -1
```

```
A2(:,2)=b
```

```
A2 = 5×5
     1   100     0     0     0
    -1     0     1     0     1
     0    50     1     0     1
     0  -120     0    -1    -1
     0     0     0     1    -1
```

```
A3(:,3)=b
```

```
A3 = 5×5
     1     2   100     0     0
    -1    -1     0     0     1
     0    -1    50     0     1
     0     1  -120    -1    -1
     0     0     0     1    -1
```

```
A4(:,4)=b
```

```
A4 = 5×5
     1     2     0   100     0
    -1    -1     1     0     1
     0    -1     1    50     1
     0     1     0  -120    -1
     0     0     0     0    -1
```

```
A5(:,5)=b
```

```
A5 = 5×5
     1     2     0     0   100
    -1    -1     1     0     0
     0    -1     1     0    50
     0     1     0    -1  -120
     0     0     0     1     0
```

```
x_1=det(A1)/det(A)
```

```
x_1 = 50.0000
```

```
x_2=det(A2)/det(A)
```

```
x_2 = 25.0000
```

```
x_3=det(A3)/det(A)
```

```
x_3 = 2.5000
```

```
x_4=det(A4)/det(A)
```

```
x_4 = 72.5000
```

```
x_5=det(A5)/det(A)
```

```
x_5 = 72.5000
```

## Problem 7

The Project One Table Template, provided in the Project One Supporting Materials section in Brightspace, shows the recommended throughput capacity of each link in the network. Put your solution for the system of equations in the third column so it can be easily compared to the maximum capacity in the second column. In the fourth column of the table, provide recommendations for how the network should be modified based on your network throughput analysis findings. The modification options can be No Change, Remove Link, or Upgrade Link. In the final column, explain how you arrived at your recommendation.

## Solution:

*Fill out the table in the original project document and export your table as an image. Then, use the **Insert** tab in the MATLAB editor to insert your table as an image.*

**MAT 350 Project One Table Template**

Complete this template by replacing the bracketed text with the relevant information.

| Network Link | Recommended Capacity (Mbps) | Solution | Recommendation | Explanation |
|---|---|---|---|---|
| $x_1$ | 60 | [50] | Keep it as it is | The speed is within the capacity |
| $x_2$ | 50 | [25] | Keep it as it is | The speed is within the capacity |
| $x_3$ | 100 | [2.5] | Swapping its capacity with x5 would be more efficient. | It is performing way below the capacit performing way above its capacity thu their capacities would improve the ove efficiency. |
| $x_4$ | 100 | [72.5] | Keep it as it is | The speed is within the capacity |
| $x_5$ | 50 | [72.5] | Needs to be upgraded | The capacity needs to be increased to network needs. |