

ELEC 2110

Electric Circuit Analysis

Gabriel Emerson

Jake Bryson

October 29, 2019

Section 002

Recitation and MATLAB: AC Mesh and Nodal Analysis

Introduction

Lab 10 is for the student to practice solving ac circuits and also learn to start using MATLAB to solve the circuit variables by inserting circuit equations.

Exercise 1

Use MATLAB to solve the following set of equations. Then convert them to polar form.

$$\begin{bmatrix} 1+j & -1 & 0 & 2-j & 0 \\ 0 & 1 & -2 & 0 & 0 \\ 0 & 0 & -1 & 1 & 0 \\ -j & -1 & 2 & 2+j & -1 \\ 0 & 0 & 0 & -3 & 1-j \end{bmatrix} \begin{bmatrix} \bar{V}_1 \\ \bar{V}_2 \\ \bar{V}_3 \\ \bar{V}_4 \\ \bar{V}_5 \end{bmatrix} = \begin{bmatrix} 2 \\ 0 \\ 12 \\ -2 \\ 0 \end{bmatrix}$$

(1)

Equations for exercise 1

The screenshot shows the MATLAB Command Window with the following code and output:

```

>> Y = [1+j -1 0 2-j 0;0 1 -2 0 0;0 0 -1 1;0;-j -1 2 2+j -1;0 0 0 -3 1-j]

Y =

```

Columns 1 through 4

```

1.0000 + 1.0000i -1.0000 + 0.0000i 0.0000 + 0.0000i 2.0000 - 1.0000i
0.0000 + 0.0000i 1.0000 + 0.0000i -2.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i -1.0000 + 0.0000i 1.0000 + 0.0000i
0.0000 - 1.0000i -1.0000 + 0.0000i 2.0000 + 0.0000i 2.0000 + 1.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i 0.0000 + 0.0000i -3.0000 + 0.0000i

```

Column 5

```

0.0000 + 0.0000i
0.0000 + 0.0000i
0.0000 + 0.0000i
-1.0000 + 0.0000i
1.0000 - 1.0000i

```

```

>> Z = [2;0;12;-2;0]

Z =

```

```

2
0
12
-2
0

```

```

>> V = Y\Z;
>> [abs(V) angle(V)*180/pi]

ans =

```

7.1063	140.7106	
35.3836	-137.2906	
17.6918	-137.2906	
12.0416	-94.7636	
25.5441	-49.7636	

(2)

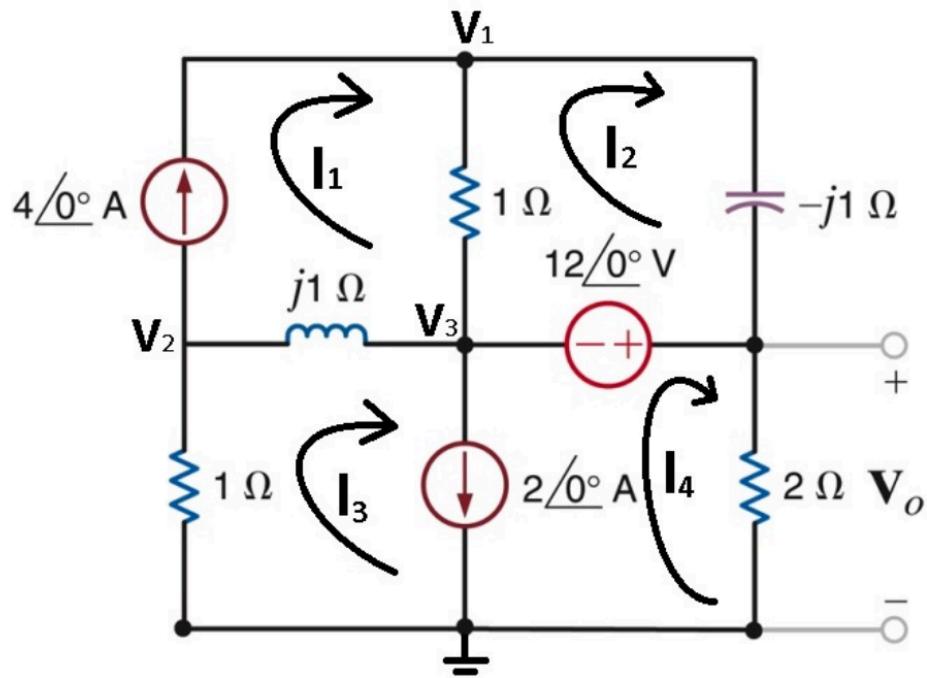
MATLAB code

Summary Table (In Polar Form)

Vector	Angle (degrees)
7.1063	140.7106
35.3836	-137.2906
17.6918	-137.2906
12.0416	-94.7636
25.5441	-49.7636

Exercise 2

Write nodal equations for the circuit and solve using MATLAB. Then repeat using mesh analysis.



(3)

Circuit for exercise 2

Lab 10

$$V_o = 6.45 \angle -7.125^\circ \text{ V}_o/2\Omega$$

$$2) \begin{bmatrix} 1+j & 0 & -1 & -j \\ 0 & 1-j & j & 0 \\ -1-j & j & 1-j & 0.5+j \\ 0 & 0 & -1 & 1 \end{bmatrix} \begin{bmatrix} 4 \\ -4 \\ -2 \\ 12 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_o \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ -1 & 1-j & 0 & 0 \\ 0 & 0 & 1 & -1 \\ -j & 0 & 1+j & 2 \end{bmatrix} \begin{bmatrix} 4 \\ -12 \\ 2 \\ 12 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix}$$

Nodal

$$-4 - \frac{V_1 - V_3}{1} - \frac{V_1 - V_o}{-j} = 0$$

$$4 - \frac{V_2 - V_3}{j} - \frac{V_2}{1} = 0$$

$$\frac{V_3 - V_1}{1} - \frac{V_3 - V_2}{j} + 2 - \frac{V_o - V_1}{-j} - \frac{V_o}{2} = 0$$

$$V_3 - V_3 = 12$$

Mesh

$$I_1 \rightarrow 4$$

$$I_2 \rightarrow (I_2 - I_1) + I_2(-j) = -12$$

$$I_3 \rightarrow I_3(1) + I_3 - I_1(j) + I_4(2) = 12$$

$$I_4 \rightarrow I_3 - I_4 = 2$$

$$V_o = 2I_4 = 3.2249 \angle -7.125^\circ (2)$$

$$= 6.4498 \angle -7.125^\circ$$

(4)

Equations for exercise 2

```

Command Window
New to MATLAB? See resources for Getting Started.

1.0000 + 1.0000i 0.0000 + 0.0000i -1.0000 + 0.0000i 0.0000 - 1.0000i
0.0000 + 0.0000i 1.0000 - 1.0000i 0.0000 + 1.0000i 0.0000 + 0.0000i
-1.0000 - 1.0000i 0.0000 + 1.0000i 1.0000 - 1.0000i 0.5000 + 1.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i -1.0000 + 0.0000i 1.0000 + 0.0000i

>> B = [4;-4;-2;12]
B =
4
-4
-2
12

>> A\B
ans =
2.4000 + 3.2000i
-5.2000 + 0.4000i
-5.6000 - 0.8000i
6.4000 - 0.8000i

>> V = A\B
V =
2.4000 + 3.2000i
-5.2000 + 0.4000i
-5.6000 - 0.8000i
6.4000 - 0.8000i

>> [abs(V) angle(V)*180/pi]
ans =
fil
4.0000 53.1301
5.2154 175.6013
5.6569 -171.8699
6.4498 -7.1250
> f2

```

Nodal equations MATLAB (5)

```

Command Window
New to MATLAB? See resources for Getting Started.

>> A = [1 0 0 0;-1 1-j 0 0;0 0 1 -1;-j 0 1+j 2]
A =
1
0.0000 + 0.0000i 0.0000 + 0.0000i 0.0000 + 0.0000i 0.0000 + 0.0000i
-1.0000 + 0.0000i 1.0000 - 1.0000i 0.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i 1.0000 + 0.0000i -1.0000 + 0.0000i
0.0000 - 1.0000i 0.0000 + 0.0000i 1.0000 + 1.0000i 2.0000 + 0.0000i

>> B = [4;-12;2;12]
B =
4
-12
2
12

>> V = A\B
V =
4.0000 + 0.0000i
-4.0000 - 4.0000i
5.2000 - 0.4000i
3.2000 - 0.4000i

>> [abs(V) angle(V)*180/pi]
ans =
4.0000 0
5.6569 -135.0000
5.2154 -4.3987
3.2249 -7.1250
f2 >> |

```

Mesh equations MATLAB (6)

Nodal Summary Table (In Polar Form)

	Vector	Angle (degrees)
V1	4.00	53.1301
V2	5.2154	175.6013
V3	5.6569	-171.8699
Vo	6.4498	-7.1250

$$Vo = Vo = 6.4498 \angle -7.1250^\circ V$$

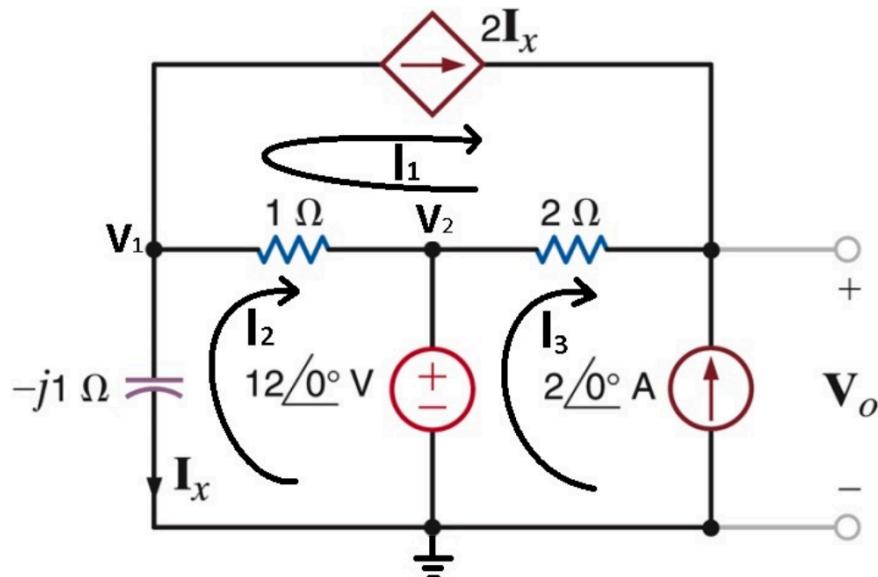
Mesh Summary Table (In Polar Form)

	Vector	Angle (degrees)
I1	4.00	0
I2	5.6569	-135.00
I3	5.2154	-4.3987
I4	3.2249	-7.1250

$$Vo = I4 * 2 = 2 * 3.2249 \angle -7.1250^\circ = 6.4498 \angle -7.1250^\circ V$$

Exercise 3

Write nodal equations for the circuit and solve using MATLAB. Then repeat using mesh analysis.



(7)

Circuit for exercise 3

$$V_0 = 2(I_1 - I_3) + 12 \angle 0^\circ = 30.78 \angle 8.97^\circ$$

3.)

$$\left[\begin{array}{cccc|cc} 1+j & -1 & 0 & 2 & 0 & V_1 \\ -j & 8 & 1 & 0 & 0 & V_2 \\ 0 & 1 & 0 & 10 & 12 & V_0 \\ 0 & -0.5 & 0.5 & -2 & 2 & I_x \end{array} \right]$$

$$\left[\begin{array}{cccc|cc} 1 & 0 & 0 & -2 & 0 & I_1 \\ 0 & 8 & 1 & 0 & 0 & I_2 \\ -1 & -j & 0 & 0 & -12 & I_3 \\ 0 & 0 & 1 & 0 & -2 & I_x \end{array} \right]$$

Node

$$2I_x - \frac{V_1 - V_2}{j} - \frac{V_1 - I_x}{j} = 0$$

$$\frac{V_2 - V_1}{1} - \frac{V_2 - V_0}{2} = 12 \quad [\cancel{V_0 = 12}]$$

$$-2I_x - \frac{V_0 - V_2}{2} = 2$$

Mesh

$$-2I_x + I_1 - I_3(2) + I_1 - I_2(1) = 0$$

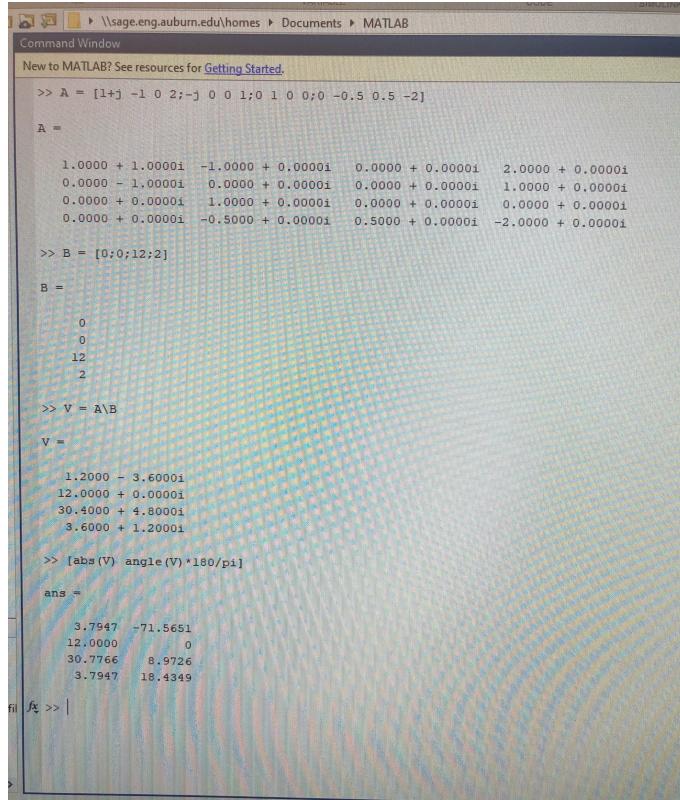
$$I_2(-j) + I_2 \cdot I_1(1) + 12 = 0$$

$$I_3 = -2$$

$$I_2 - I_x = 0$$

(8)

Equations for exercise 3



```

>> A = [1+j -1 0 2;-j 0 0 1;0 1 0 0;0 -0.5 0.5 -2]
A =

```

1.0000 + 1.0000i	-1.0000 + 0.0000i	0.0000 + 0.0000i	2.0000 + 0.0000i
0.0000 - 1.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	1.0000 + 0.0000i
0.0000 + 0.0000i	1.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i
0.0000 + 0.0000i	-0.5000 + 0.0000i	0.5000 + 0.0000i	-2.0000 + 0.0000i

```

>> B = [0;0;12;2]
B =

```

0
0
12
2

```

>> V = A\B
V =

```

1.2000 - 3.6000i
12.0000 + 0.0000i
30.4000 + 4.8000i
3.6000 + 1.2000i

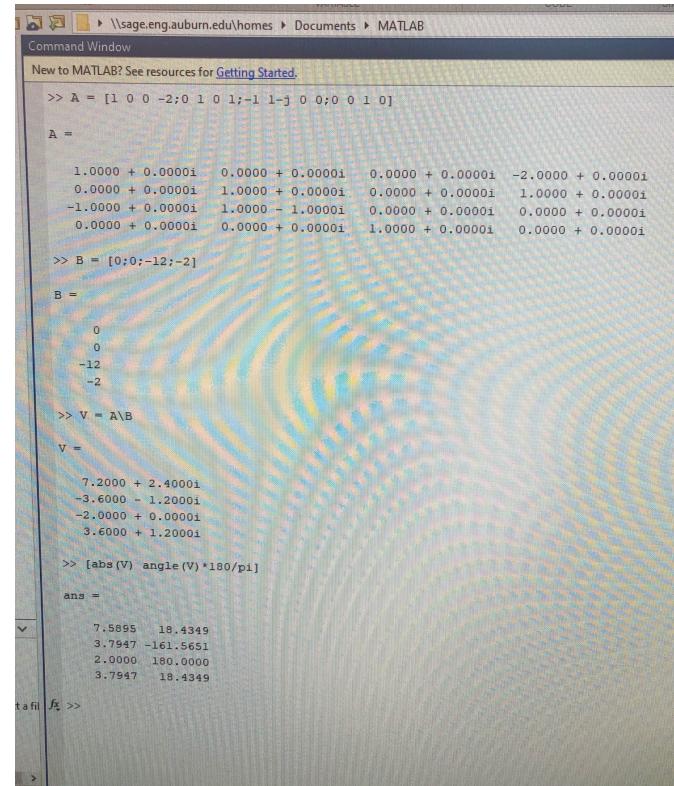
```

>> [abs(V) angle(V)*180/pi]
ans =

```

3.7947 -71.5651
12.0000 0
30.7766 8.9726
3.7947 18.4349

Nodal equations MATLAB (9)



```

>> A = [1 0 0 -2;0 1 0 1;-1 1-j 0 0;0 0 1 0]
A =

```

1.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	-2.0000 + 0.0000i
0.0000 + 0.0000i	1.0000 + 0.0000i	0.0000 + 0.0000i	1.0000 + 0.0000i
-1.0000 + 0.0000i	1.0000 - 1.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	1.0000 + 0.0000i	0.0000 + 0.0000i

```

>> B = [0;0;-12;-2]
B =

```

0
0
-12
-2

```

>> V = A\B
V =

```

7.2000 + 2.4000i
-3.6000 - 1.2000i
-2.0000 + 0.0000i
3.6000 + 1.2000i

```

>> [abs(V) angle(V)*180/pi]
ans =

```

7.5895 18.4349
3.7947 -161.5651
2.0000 180.0000
3.7947 18.4349

Mesh equations MATLAB (10)

Nodal Summary Table (In Polar Form)

	Vector	Angle (degrees)
V1	3.7947	-71.5651
V2	12.00	0
Vo	30.7766	8.9726
Ix	3.7947	18.4349

$$Vo = Vo = 30.7766 < 8.9726 \text{ V}$$

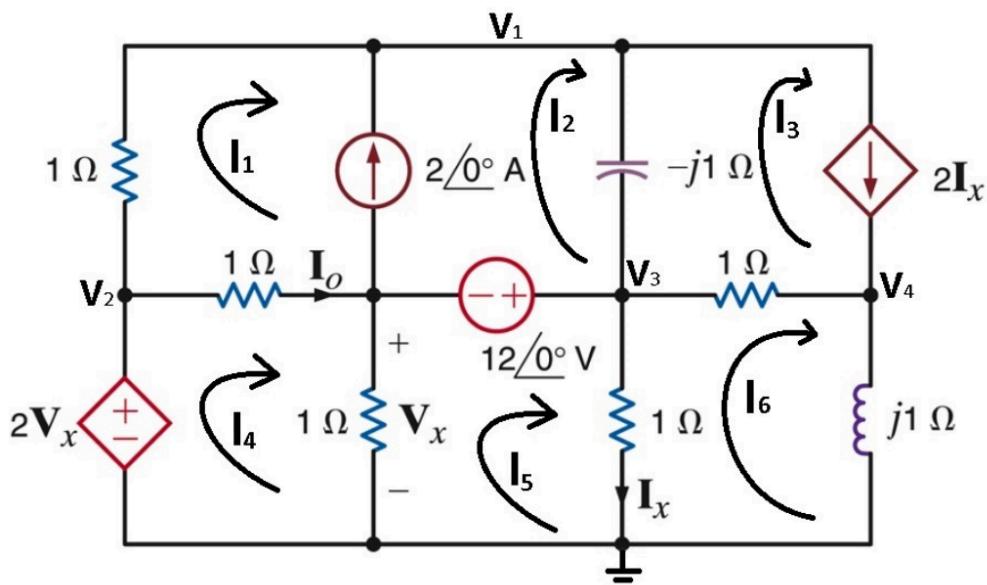
Mesh Summary Table (In Polar Form)

	Vector	Angle (degrees)
I1	7.5895	18.4349
I2	3.7947	-161.5651
I3	2.00	180
Ix	3.7947	18.4349

$$Vo = 2(I1 - I3) + 12 = 2(7.5895 < 18.4349 - 2.00 < 180) + 12 < 0 = 30.7766 < 8.9726 \text{ V}$$

Exercise 4

Write nodal equations for the circuit and solve using MATLAB. Then repeat using mesh analysis.



Circuit for exercise 4

(11)

$$I_0 = \frac{V_2 - V_x}{1} = 17.69 L - 137.29^\circ$$

Nodal

$$4.) \begin{bmatrix} 1+j & -1 & -j & 0 & 0 & 2 \\ 0 & 0 & 1 & 0 & 0 & -1 \\ 0 & 1 & 0 & 0 & -2 & 0 \\ -j & -1 & 2+j & -1 & 2 & 0 \\ 0 & 0 & 1 & 0 & -1 & 0 \\ 0 & 0 & -1 & 1-j & 0 & -2 \end{bmatrix} \begin{bmatrix} 2 \\ 0 \\ 0 \\ -2 \\ 12 \\ 0 \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \\ V_3 \\ V_4 \\ V_x \\ I_x \end{bmatrix}$$

Mesh

$$\begin{array}{l|c|c|c|c|c|c|c|c|c|c} I_1 & -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 2 \\ I_2 & 2 & -j & j & -1 & 0 & 0 & 0 & 0 & 0 & -12 \\ I_3 & 0 & 6 & 1 & 0 & 0 & 0 & 0 & -2 & 0 \\ I_4 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & -1 & 0 \\ I_5 & -1 & 0 & 0 & 2 & -1 & 6 & -2 & 0 & 0 \\ I_6 & 0 & 0 & 0 & 1 & -1 & 0 & -1 & 0 & 0 \\ V_x & 0 & 0 & 0 & -1 & 2 & -1 & 0 & 0 & 12 \\ I_x & 0 & 0 & -1 & 0 & -1 & 2+j & 0 & 0 & 0 \end{array}$$

$$I_0 = I_4 - I_1$$

(12)

Equations for exercise 4

```

Columns 1 through 5
1.0000 + 1.0000i -1.0000 + 0.0000i 0.0000 - 1.0000i 0.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i 1.0000 + 0.0000i 0.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 1.0000 + 0.0000i 0.0000 + 0.0000i 0.0000 + 0.0000i -2.0000 + 0.0000i
0.0000 - 1.0000i -1.0000 + 0.0000i 2.0000 + 1.0000i -1.0000 + 0.0000i 2.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i 1.0000 + 0.0000i 0.0000 + 0.0000i -1.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i -1.0000 + 0.0000i 1.0000 - 1.0000i 0.0000 + 0.0000i

Column 6
2.0000 + 0.0000i
-1.0000 + 0.0000i
0.0000 + 0.0000i
0.0000 + 0.0000i
0.0000 + 0.0000i
-2.0000 + 0.0000i

>> B = [2;0;0;-2;12;0]

B =
2
0
0
-2
12
0

>> V = A\B

V =

```

(13)

Nodal equations MATLAB

****Not in Polar form****

```

Columns 1 through 5
-1.0000 + 0.0000i 1.0000 + 0.0000i 0.0000 + 0.0000i -0.0000 + 0.0000i 0.0000 + 0.0000i
2.0000 + 0.0000i 0.0000 - 1.0000i 0.0000 + 1.0000i -1.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i 1.0000 + 0.0000i 0.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i 0.0000 + 0.0000i 0.0000 + 0.0000i 1.0000 + 0.0000i
-1.0000 + 0.0000i 0.0000 + 0.0000i 0.0000 + 0.0000i 0.0000 + 0.0000i 2.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i 0.0000 + 0.0000i 1.0000 + 0.0000i -1.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i 0.0000 + 0.0000i -1.0000 + 0.0000i 2.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i -1.0000 + 0.0000i 0.0000 + 0.0000i -1.0000 + 0.0000i

Columns 6 through 8
1
0.0000 + 0.0000i 0.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i 0.0000 + 0.0000i -2.0000 + 0.0000i
-1.0000 + 0.0000i 0.0000 + 0.0000i -1.0000 + 0.0000i
0.0000 + 0.0000i -2.0000 + 0.0000i 0.0000 + 0.0000i
0.0000 + 0.0000i -1.0000 + 0.0000i 0.0000 + 0.0000i
-1.0000 + 0.0000i 0.0000 + 0.0000i 0.0000 + 0.0000i
2.0000 + 1.0000i 0.0000 + 0.0000i 0.0000 + 0.0000i

>> B = [2;-12;0;0;0;0;12;0]

B =
2
-12
0
0
0
0
12
0

>> V = A\B

V =

```

Mesh equations MATLAB part 1

(14)

```

V =

```

-20.5000 - 28.5000i
-18.5000 - 28.5000i
-2.0000 - 24.0000i
-33.5000 - 40.5000i
-20.5000 - 28.5000i
-19.5000 - 16.5000i
-13.0000 - 12.0000i
-1.0000 - 12.0000i

Mesh equations MATLAB part 2

****Not in Polar form****

Nodal Summary Table (In Polar Form)

	Vector	Angle (degrees)
V1	7.10634	140.711
V2	35.3836	-137.291
V3	12.0416	-94.7636
V4	25.5441	-130.236
Vx	17.6918	-137.291
Ix	12.0416	-94.7636

$$I_o = (V_2 - V_x)/1 = 35.3836 \angle -137.291^\circ - 17.6918 \angle -137.291^\circ = 17.69 \angle -137.291^\circ \text{ A}$$

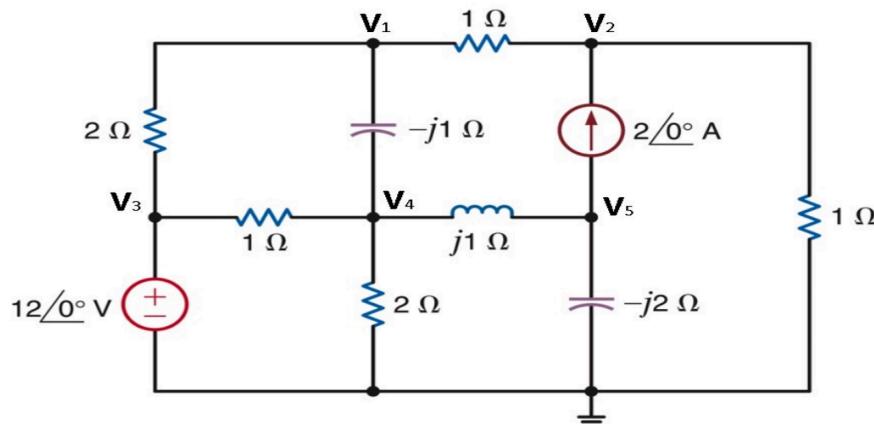
Mesh Summary Table (In Polar Form)

	Vector	Angle (degrees)
I1	35.107	-125.727
I2	33.9779	-122.989
I3	24.0832	-94.7636
I4	52.5595	-129.596
I5	35.107	-125.727
I6	25.5441	-139.764
Vx	17.6918	-137.291
Ix	12.0416	-94.7636

$$I_o = I_4 - I_1 = 52.5595 \angle -129.596^\circ - 35.107 \angle -125.727^\circ = 17.69 \angle -137.291^\circ \text{ A}$$

Exercise 5

Write nodal equations for the circuit and solve using MATLAB.



Circuit for exercise 5

(16)

Lab 10

Q Nodal

$$5.) \left[\begin{array}{ccccc|c} 1.5+j & -1 & -0.5 & -j & 0 & 0 \\ -1 & 2 & 0 & 0 & 0 & 2 \\ 0 & 0 & 1 & 0 & 0 & 12 \\ -j & 0 & -1 & 1.5 & j & 0 \\ 0 & 0 & 0 & j & -0.5j & -2 \end{array} \right] \left[\begin{array}{c} V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \end{array} \right]$$

$$\frac{V_1 - V_3}{2} - \frac{V_1 - V_4}{j} - \frac{V_1 - V_2}{1} = 0$$

$$\frac{V_2 - V_1}{1} - 2 - \frac{V_2}{1} = 0$$

$$\frac{V_3 - V_1}{2} - \frac{V_3 - V_4}{1} = 0 \quad | * V_3 = 12$$

$$\frac{V_4 - V_1}{-j} - \frac{V_4 - V_3}{1} - \frac{V_4}{2} - \frac{V_4 - V_5}{j} = 0$$

$$\frac{V_5 - V_4}{j} + 2 - \frac{V_5}{-j2}$$

~~$$\text{Solved } V_1 = 6.89 L - 17.38$$~~

(17)

Equations for exercise 5

The screenshot shows the MATLAB Command Window with the following code and output:

```

>> A = [1.5+j -1 -0.5 -j 0;-1 2 0 0 0;0 0 1 0 0;-j 0 -1 1.5 j;0 0 0 j -0.5j]
A =
    1.5000 + 1.0000i   -1.0000 + 0.0000i   -0.5000 + 0.0000i   0.0000 - 1.0000i   0.0000 + 0.0000i
   -1.0000 + 0.0000i   2.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
    0.0000 + 0.0000i   0.0000 + 0.0000i   1.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 - 1.0000i   0.0000 + 0.0000i   -1.0000 + 0.0000i   1.5000 + 0.0000i   0.0000 + 1.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 1.0000i   0.0000 - 0.5000i

>> B = [0;2;12;0;-2]
B =
    0
    2
   12
    0
   -2

>> V = A\B
V =
    6.5800 - 2.0600i
    4.2900 - 1.0300i
   12.0000 - 0.0000i
    4.5200 - 1.6400i
    9.0400 - 7.2800i

>> [abs(V) angle(V)*180/pi]
ans =
    6.8949  -17.3838
    4.4119  -13.5008
   12.0000   -0.0000
    4.8083  -19.9424
   11.6069  -38.8448

```

(18)

Nodal equations MATLAB

Nodal Summary Table

	Vector	Angle (degrees)
V1	6.8949	-17.3838
V2	4.4119	-13.5008
V3	12.00	0
V4	4.8083	-19.9424
V5	11.6069	-38.8448

Conclusion

Nodal and Mesh analysis are tools critical for an electrical engineers' daily job. This lab is very helpful in learning to progress skills with these analysis methods, in AC circuits. AC circuit analysis is important since it is most common in the United States.

Bibliography

1. MATLAB equation to solve in exercise 1
2. MATLAB solution and solving
3. Circuit for exercise 2
4. Hand written equations exercise 2
5. Nodal equations exercise 2
6. Mesh equations exercise 2
7. Circuit for exercise 3
8. Hand written equations exercise 3
9. Nodal equations exercise 3
10. Mesh equations exercise 3
11. Circuit for exercise 4
12. Hand written equations exercise 4
13. Nodal equations exercise 4
14. Mesh equations exercise 4 part 1
15. Mesh equations exercise 4 part 2
16. Circuit for exercise 5
17. Hand written equations exercise 5
18. Nodal equations exercise 5