Lecture: Solving Systems of Linear Equations in MATLAB

The material developed here supplements the section in [1] titled Systems of linear equations, specifically as a MATLAB live script-based alternative to the subsection titled "Solving systems of linear equations in a spreadsheet." Example problems are from [1] - [3]. Additional supporting information is available at https://github.com/ashleefv/MEBLinearSystems

Sources:

[1] M. W. Liberatore, Material and Energy Balances ZyBook. Electronic, interactive textbook: ZyBooks, 2019.

[2] R. M. Felder, R. W. Rousseau, and L. G. Bullard, *Elementary Principles of Chemical Processes*, 4th ed. Hoboken, NJ: John Wiley & Sons, 2016.

[3] R. M. Murphy, *Introduction to Chemical Processes: Principles, Analysis, Synthesis*, 2nd ed. New York, NY: McGraw Hill, 2023.

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Learning Objectives

- Solve a system of linear equations using the backslash operator in MATLAB.

Systems of Linear Equations in MATLAB

Systems of linear equations consist of coefficients, constants, and variables, which can be arranged into matrices. The matrix form to express a system of linear equations is matrix A for the coefficients, matrix x for the variables, and matrix b for the constants, which yields the formula $\mathrm{Ax} = b$. Solving for the variables involves taking the transpose of A multiplied by b, or $A^{-1}b = x$. Solving for the variables of a system of linear equations in MATLAB involves using the backslash operator, \

$x = A \setminus b$ will return the solution to $x = A^{-1}b$.

Worked Example

For example, let's look at the following system of linear equations.

$$-3x_1 + 4x_2 - 9 = -2x_3$$
$$x_1 - 5 = 4x_3 - 6x_2 + 2$$
$$-2x_1 - 5x_2 - 8x_3 - 4 = 0$$

First, separate the constant terms and the variable terms resulting the following system of linear equations.

$$-3x_1 + 4x_2 + 2x_3 = 9$$
$$x_1 + 6x_2 - 4x_3 = 7$$
$$-2x_1 - 5x_2 - 8x_3 = 4$$

Second, create the coefficient matrix A. Each row of the coefficient matrix represents the coefficients of one of the linear equations and each column represents the coefficients of one of the variables across all three linear equations. A has the same number of rows and columns, which is equal to the total unknown variables and the number of equations in the system.

```
A = [-3  4  2;
      1  6 -4;
     -2 -5 -8]
```

```
A = 3×3
    -3     4     2
     1     6    -4
    -2    -5    -8
```

Next, create column vector of constant terms, matrix b. Each row of the column vector represents the isolated constant term of a linear equation.

Note: The order of the represented linear equations is arbitrary but should match the order of the rows seen in the coefficient matrix.

```
b = [9;
     7;
     4]
```

```
b = 3×1
     9
     7
     4
```

Finally, use the backslash operator to solve for the values of x_1, x_2, and x_3. The solution will take the form of a column vector, x, with the first, second, and third rows representing the values of x_1, x_2, and x_3 respectively.

```
x = A\b
```

```
x = 3×1
   -2.0213
    1.0638
   -0.6596
```

Note: If the first and second column of the coefficient matrix a were exchanged, the solution would take the form of a column vector, x, with the first, second, and third rows representing the values of x_2, x_1, and x_3 respectively. The order of the columns in the coefficient matrix determines the order of the rows in the solution vector.

```
A = [ 4 -3  2;
      6  1 -4;
     -5 -2 -8];

b = [9;
     7;
     4];

x = A\b
```

```
x = 3×1
    1.0638
   -2.0213
   -0.6596
```

Example 1

Exercise 1.10.1 from [1]

EXERCISE | 1.10.1: Balancing a chemical reaction using a spreadsheet. All solutions visible to students

Rose and Claudio are out camping and decide to have a fire. They have some pine firewood with a chemical composition of $C_{3.2}H_{4.6}O_{2.1}$. They need to balance a combustion chemical reaction before they can figure out how much heat the fire will produce. Luckily, their portable electronic device has a spreadsheet program. Complete the following steps to balance the reaction containing three unknown variables ($\mathbf{x_1}$, $\mathbf{x_2}$, $\mathbf{x_3}$) : $\mathbf{x_1}$ $C_{3.2}H_{4.6}O_{2.1}$ + 14 $O_2 \rightarrow$ $\mathbf{x_2}$ CO_2 + $\mathbf{x_3}$ H_2O.

(a) Write a set of atom balances. Specifically, write equations for carbon, hydrogen, and oxygen that equate the number of atoms on the left hand side of the reaction with the number of atoms on the right side of the reaction.

Solution Visible to students

The atom balances can be written as:

Carbon: $x_1 \cdot 3.2 = x_2 \cdot 1$

Hydrogen: $x_1 \cdot 4.6 = x_3 \cdot 2$

Oxygen: $x_1 \cdot 2.1 + 14 \cdot 2 = x_2 \cdot 2 + x_3 \cdot 1$

The atom balances are the system of linear equations:

$$
\begin{aligned}
3.2x_1 &= x_2 \\
4.6x_1 &= 2x_3 \\
2.1x_1 + 14 * 2 &= 2x_2 + x_3
\end{aligned}
$$

Separate the constant terms and the variable terms resulting in the following system of linear equations.

$$3.2x_1 - 1x_2 + 0x_3 = 0$$
$$4.6x_1 - 0x_2 - 2x_3 = 0$$
$$2.1x_1 - 2x_2 - 1x_3 = -28$$

As there are three equations and three unknowns, A will have three rows and three columns, b will have three rows, and x will return the solutions to the three unknown variables. Enter in the corresponding values below (expanding the number of rows or columns, if needed for new problems) and press run.

```
A = [ 3.2  -1  0;
      4.6  -0 -2;
      2.1  -2 -1]
```

```
A = 3×3
    3.2000   -1.0000         0
    4.6000         0   -2.0000
    2.1000   -2.0000   -1.0000
```

```
b = [  0;
       0;
     -28]
```

```
b = 3×1
     0
     0
   -28
```

```
x = A\b
```

```
x = 3×1
    4.2424
   13.5758
    9.7576
```

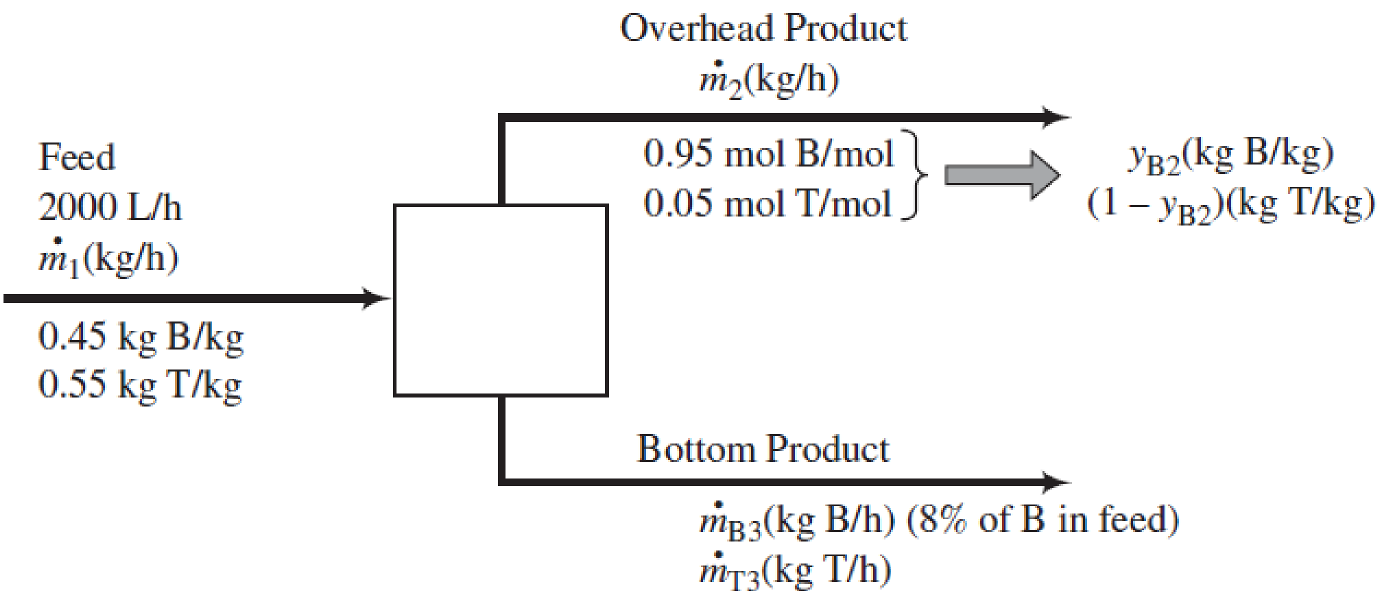
Example 2

Example 4.3-5 from [2]

Example 4.3-5 Material Balances on a Distillation Column

Equipment Encyclopedia
distillation column
www.wiley.com/college/felder

A liquid mixture containing 45.0% benzene (B) and 55.0% toluene (T) by mass is fed to a distillation column. A product stream leaving the top of the column (the *overhead product*) contains 95.0 mole% B, and a bottom product stream contains 8.0% of the benzene fed to the column (meaning that 92% of the benzene leaves with the overhead product). The volumetric flow rate of the feed stream is 2000 L/h and the specific gravity of the feed mixture is 0.872. Determine the mass flow rate of the overhead product stream and the mass flow rate and composition (mass fractions) of the bottom product stream (a) solving the equations manually, and (b) using an equation-solving program.



System of equations:

Write and solve the system equations. The four system equations (two material balances, feed density relationship, and benzene split equation) may be written in that (or any other) order.

Mass balance:
$$\dot{m}_1 = \dot{m}_2 + \dot{m}_{B3} + \dot{m}_{T3} \quad \textbf{(1)}$$

Benzene balance:
$$0.45\dot{m}_1 = 0.942\dot{m}_2 + \dot{m}_{B3} \quad \textbf{(2)}$$

Conversion of volumetric flow rate:
$$\dot{m}_1 = \left(2000\,\frac{\text{L}}{\text{h}}\right)\left(0.872 \times 1.00\,\frac{\text{kg}}{\text{L}}\right) \quad \textbf{(3)}$$

Benzene split:
$$\dot{m}_{B3} = 0.08(0.45\dot{m}_1) \quad \textbf{(4)}$$

The $x = A \setminus b$ procedure can be used to solve systems of linear equations of any size. Using the same procedure as the worked example, solve the following system of linear equations.

$$\dot{m}_1 = \dot{m}_2 + \dot{m}_{B3} + \dot{m}_{T3}$$
$$0.45\dot{m}_1 = 0.942\dot{m}_2 + \dot{m}_{B3}$$
$$\dot{m}_1 = \left(2000\,\frac{\text{L}}{\text{h}}\right)\left(0.872 \times 1.00\,\frac{\text{kg}}{\text{L}}\right)$$
$$\dot{m}_{B3} = 0.08(0.45\dot{m}_1)$$

Separate the constant terms and the variable terms resulting in the following system of linear equations.

$$-1\dot{m}_1 + 1\dot{m}_2 + 1\dot{m}_{B3} + 1\dot{m}_{T3} = 0$$

$$0.45\dot{m}_1 - 0.942\dot{m}_2 - 1\dot{m}_{B3} + 0\dot{m}_{T3} = 0$$

$$1\dot{m}_1 + 0\dot{m}_2 + 0\dot{m}_{B3} + 0\dot{m}_{T3} = \left(2000\,\frac{\mathrm{L}}{\mathrm{h}}\right)\left(0.872 \times 1.00\,\frac{\mathrm{kg}}{\mathrm{L}}\right)$$

$$-0.08(0.45\dot{m}_1) + 0\dot{m}_2 + 1\dot{m}_{B3} + 0\dot{m}_{T3} = 0$$

As there are four equations and four unknowns, A will have four rows and four columns, b will have four rows, and x will return the solutions to the four unknown variables. Enter in the corresponding values below (expanding the number of rows or columns, if needed for new problems) and press run.

```
A = [ -1          1       1  1;
       0.45      -0.942  -1  0;
       1          0       0  0;
      -0.08*0.45  0       1  0]
```

```
A = 4×4
   -1.0000    1.0000    1.0000    1.0000
    0.4500   -0.9420   -1.0000         0
    1.0000         0         0         0
   -0.0360         0    1.0000         0
```

```
b = [0;
     0;
     2000*.872;
     0]
```

```
b = 4×1
           0
           0
        1744
           0
```

```
x = A\b
```

```
x = 4×1
10^3 ×
    1.7440
    0.7665
    0.0628
    0.9147
```

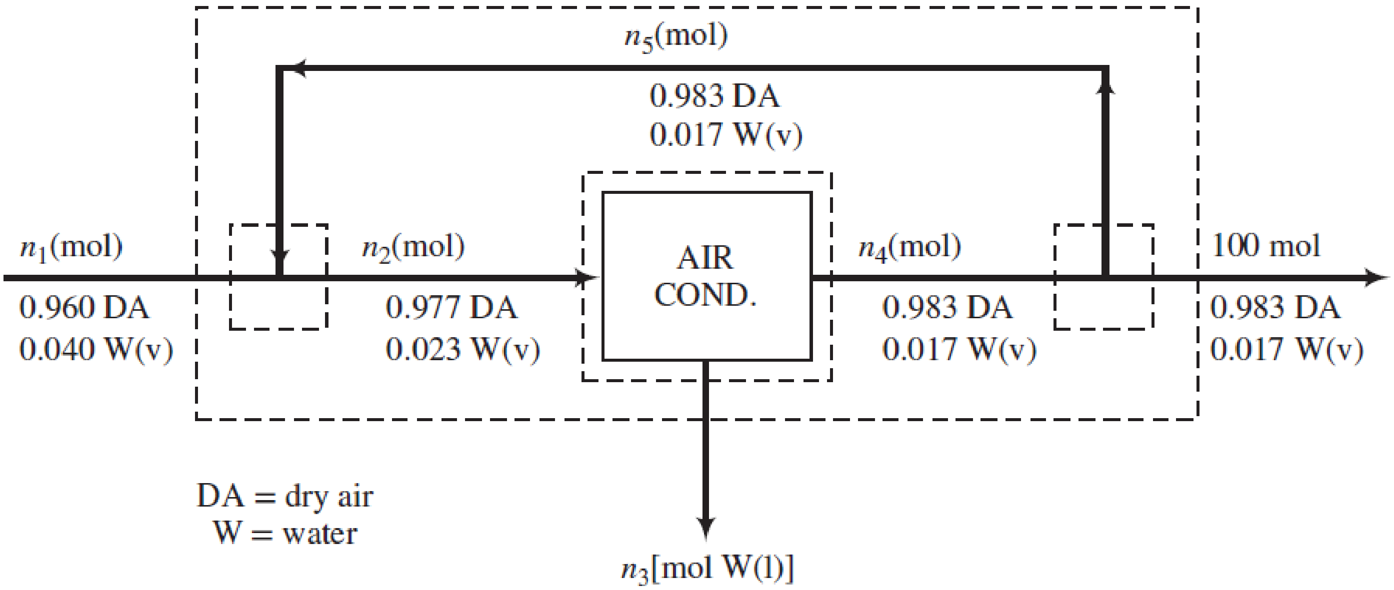
Example 3

Example 4.5-1 from [2]

Example 4.5-1 Material and Energy Balances on an Air Conditioner

Equipment Encyclopedia
reactor, condenser
www.wiley.com/college/felder

Fresh air containing 4.00 mole% water vapor is to be cooled and dehumidified to a water content of 1.70 mole% H_2O. A stream of fresh air is combined with a recycle stream of previously dehumidified air and passed through the cooler. The blended stream entering the unit contains 2.30 mole% H_2O. In the air conditioner, some of the water in the feed stream is condensed and removed as liquid. A fraction of the dehumidified air leaving the cooler is recycled and the remainder is delivered to a room. Taking 100 mol of dehumidified air delivered to the room as a basis of calculation, calculate the moles of fresh feed, moles of water condensed, and moles of dehumidified air recycled (a) manually, and (b) using Excel's Solver.



System of equations:

Equation
$n_1 + n_5 = n_2$
$0.04^* n_1 + 0.017^* n_5 = 0.023^* n_2$
$n_2 = n_3 + n_4$
$0.023^* n_2 = n_3 + 0.017^* n_4$
$n_4 = n_5 + 100$

The $x = A \backslash b$ procedure can be used to solve systems of linear equations of any size. Using the same procedure as the worked example, solve the following system of linear equations.

$$n_1 + n_5 = n_2$$
$$0.04n_1 + 0.017n_5 = 0.023n_2$$
$$n_2 = n_3 + n_4$$
$$0.023n_2 = n_3 + 0.017n_4$$
$$n_4 = n_5 + 100$$

Separate the constant terms and the variable terms resulting in the following system of linear equations.

$$1n_1 - 1n_2 + 0n_3 + 0n_4 + 1n_5 = 0$$
$$0.04n_1 - 0.023n_2 + 0n_3 + 0n_4 + 0.017n_5 = 0$$
$$0n_1 - 1n_2 + 1n_3 + 1n_4 + 0n_5 = 0$$
$$0n_1 + 0.023n_2 - 1n_3 - 0.017n_4 + 0n_5 = 0$$
$$0n_1 + 0n_2 + 0n_3 + 1n_4 - 1n_5 = 100$$

As there are five equations and five unknowns, A will have five rows and five columns, b will have five rows, and x will return the solutions to the five unknown variables. Enter in the corresponding values below (expanding the number of rows or columns, if needed for new problems) and press run.

```
A = [ 1    -1      0   0      1;
      0.04 -0.023  0   0      0.017;
      0    -1      1   1      0;
      0     0.023 -1  -0.017  0;
      0     0      0   1     -1]
```

```
A = 5×5
    1.0000   -1.0000         0         0    1.0000
    0.0400   -0.0230         0         0    0.0170
         0   -1.0000    1.0000    1.0000         0
         0    0.0230   -1.0000   -0.0170         0
         0         0         0    1.0000   -1.0000
```

```
b = [0;
     0;
     0;
     0;
     100]
```

```
b = 5×1
     0
     0
     0
     0
   100
```

```
x = A\b
```

```
x = 5×1
  102.3958
  392.5174
    2.3958
  390.1215
```

Example 4

Problem 4.67 from [2]

4.67. Methane and oxygen react in the presence of a catalyst to form formaldehyde. In a parallel reaction, methane is oxidized to carbon dioxide and water:

$$CH_4 + O_2 \rightarrow HCHO + H_2O$$

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

The feed to the reactor contains equimolar amounts of methane and oxygen. Assume a basis of 100 mol feed/s.

(a) Draw and label a flowchart. Use a degree-of-freedom analysis based on extents of reaction to determine how many process variable values must be specified for the remaining variable values to be calculated.

(b) Use Equation 4.6-7 to derive expressions for the product stream component flow rates in terms of the two extents of reaction, ξ_1 and ξ_2.

(c) The fractional conversion of methane is 0.900 and the fractional yield of formaldehyde is 0.855. Calculate the molar composition of the reactor output stream and the selectivity of formaldehyde production relative to carbon dioxide production.

The $x = A \setminus b$ procedure can be used to solve systems of linear equations of any size. Using the same procedure as the worked example, solve the following system of linear equations.

$$\dot{n}_1 = 50 - \xi_1 - \xi_2$$

$$\dot{n}_2 = 50 - \xi_1 - 2\xi_2$$

$$\dot{n}_3 = \xi_1$$

$$\dot{n}_4 = \xi_1 + 2\xi_2$$

$$\dot{n}_5 = \xi_2$$

Use the fractional conversion and fractional yield to solve for $\dot{n}_1$ and $\dot{n}_3$. Once we know the values of $\dot{n}_1$ and $\dot{n}_3$, there are five equations and five remaining unkowns.

$$\underline{\text{Fractional conversion}}: \frac{(50 - \dot{n}_1)}{50} = 0.900 \Rightarrow \dot{n}_1 = 5.00 \text{ mol } CH_4 \text{ /s}$$

$$\underline{\text{Fractional yield}}: \frac{\dot{n}_3}{50} = 0.855 \Rightarrow \dot{n}_3 = 42.75 \text{ mol HCHO /s}$$

Separate the constant terms and the variable terms resulting in the following system of linear equations.

$$1\xi_1 + 1\xi_2 + 0n_2 + 0n_4 + 0n_5 = 50 - n_1$$
$$1\xi_1 + 2\xi_2 + 1n_2 + 0n_4 + 0n_5 = 50$$
$$1\xi_1 + 0\xi_2 + 0n_2 + 0n_4 + 0n_5 = n_3$$
$$1\xi_1 + 2\xi_2 + 0n_2 - 1n_4 + 0n_5 = 0$$
$$0\xi_1 + 1\xi_2 + 0n_2 + 0n_4 - 1n_5 = 0$$

As there are five equations and five unknowns, A will have five rows and five columns, b will have five rows, and x will return the solutions to the five unknown variables. Enter in the corresponding values below (expanding the number of rows or columns, if needed for new problems) and press run.

```
% initialize A and b to zeros for matrix and vector of the correct size for
% this problem
numEqns = 5;
A = zeros(numEqns);
b = zeros(numEqns,1);
n1 = 5;
n3 = 0.855*50;
eqn = 1;
    A(eqn,1) = 1;
    A(eqn,2) = 1;
    b(eqn) = 50-n1;
eqn = 2;
    A(eqn,1) = 1;
    A(eqn,2) = 2;
    A(eqn,3) = 1;
    b(eqn) = 50;
eqn = 3;
    A(eqn,1) = 1;
    b(eqn) = n3;
eqn = 4;
    A(eqn,1) = 1;
    A(eqn,2) = 2;
    A(eqn,4) = -1;
eqn = 5;
    A(eqn,2) = 1;
    A(eqn,5) = -1;
A
```

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

```
b
```

```
b = 5×1
   45.0000
   50.0000
```

```
    42.7500
          0
          0
```

```
x = A\b
```

```
x = 5×1
    42.7500
     2.2500
     2.7500
    47.2500
     2.2500
```

Example 5

Example 3.3 from [3]

Mole Balances: Urea Manufacture from Cheaper Reactants

Urea can be manufactured from methane (CH_4), water, and nitrogen via a pathway requiring four chemical reactions:

$$CH_4 + H_2O \rightarrow CO + 3H_2 \quad \text{(R1)}$$

$$CO + H_2O \rightarrow CO_2 + H_2 \quad \text{(R2)}$$

$$N_2 + 3H_2 \rightarrow 2NH_3 \quad \text{(R3)}$$

$$NH_3 + 0.5CO_2 \rightarrow 0.5(NH_2)_2CO + 0.5H_2O \quad \text{(R4)}$$

We'd like to design a process to make 90 gmol/min urea at steady state, from the raw materials methane, water, and nitrogen. Furthermore, there should be no reactants (CH_4, H_2O, or N_2) nor any CO, CO_2, or NH_3 leaving the process. (See sketch.) What should be the reactant feed rates? What are the byproducts?

System of equations:

$$0 = \dot{n}_{M1} + \nu_{M1}\dot{\xi}_1 = \dot{n}_{M1} - \dot{\xi}_1$$

$$0 = \dot{n}_{W1} + \nu_{W1}\dot{\xi}_1 + \nu_{W2}\dot{\xi}_2 + \nu_{W4}\dot{\xi}_4 = \dot{n}_{W1} - \dot{\xi}_1 - \dot{\xi}_2 + 0.5\dot{\xi}_4$$

$$0 = \nu_{CO1}\dot{\xi}_1 + \nu_{CO2}\dot{\xi}_2 = \dot{\xi}_1 - \dot{\xi}_2$$

$$0 = \nu_{CD2}\dot{\xi}_2 + \nu_{CD4}\dot{\xi}_4 = \dot{\xi}_2 - 0.5\dot{\xi}_4$$

$$\dot{n}_{H2} = \nu_{H1}\dot{\xi}_1 + \nu_{H2}\dot{\xi}_2 + \nu_{H3}\dot{\xi}_3 = 3\dot{\xi}_1 + \dot{\xi}_2 - 3\dot{\xi}_3$$

$$0 = \dot{n}_{N1} + \nu_{N3}\dot{\xi}_3 = \dot{n}_{N1} - \dot{\xi}_3$$

$$0 = \nu_{A3}\dot{\xi}_3 + \nu_{A4}\dot{\xi}_4 = 2\dot{\xi}_3 - \dot{\xi}_4$$

$$\dot{n}_{U2} = 90 \text{ gmol/min} = \nu_{U4}\dot{\xi}_4 = 0.5\dot{\xi}_4$$

The $x = A \setminus b$ procedure can be used to solve systems of linear equations of any size. Using the same procedure as the worked example, solve the following system of linear equations.

$$0 = \dot{n}_{M1} + v_{M1}\dot{\xi}_1 = \dot{n}_{M1} - \dot{\xi}_1$$

$$0 = \dot{n}_{W1} + v_{W1}\dot{\xi}_1 + v_{W2}\dot{\xi}_2 + v_{W4}\dot{\xi}_4 = \dot{n}_{W1} - \dot{\xi}_1 - \dot{\xi}_2 + 0.5\dot{\xi}_4$$

$$0 = v_{CO1}\dot{\xi}_1 + v_{CO2}\dot{\xi}_2 = \dot{\xi}_1 - \dot{\xi}_2$$

$$0 = v_{CD2}\dot{\xi}_2 + v_{CD4}\dot{\xi}_4 = \dot{\xi}_2 - 0.5\dot{\xi}_4$$

$$\dot{n}_{H2} = v_{H1}\dot{\xi}_1 + v_{H2}\dot{\xi}_2 + v_{H3}\dot{\xi}_3 = 3\dot{\xi}_1 + \dot{\xi}_2 - 3\dot{\xi}_3$$

$$0 = \dot{n}_{N1} + v_{N3}\dot{\xi}_3 = \dot{n}_{N1} - \dot{\xi}_3$$

$$0 = v_{A3}\dot{\xi}_3 + v_{A4}\dot{\xi}_4 = 2\dot{\xi}_3 - \dot{\xi}_4$$

$$\dot{n}_{U2} = 90 \text{ gmol/min} = v_{U4}\dot{\xi}_4 = 0.5\dot{\xi}_4$$

Separate the constant terms and the variable terms resulting in the following system of linear equations.

$$1\dot{n}_{M1} + 0\dot{n}_{W1} + 0\dot{n}_{N1} + 0\dot{n}_{H2} - 1\dot{\xi}_1 + 0\dot{\xi}_2 + 0\dot{\xi}_3 + 0\dot{\xi}_4 = 0$$

$$0\dot{n}_{M1} + 1\dot{n}_{W1} + 0\dot{n}_{N1} + 0\dot{n}_{H2} - 1\dot{\xi}_1 - 1\dot{\xi}_2 + 0\dot{\xi}_3 + 0.5\dot{\xi}_4 = 0$$

$$0\dot{n}_{M1} + 0\dot{n}_{W1} + 0\dot{n}_{N1} + 0\dot{n}_{H2} + 1\dot{\xi}_1 - 1\dot{\xi}_2 + 0\dot{\xi}_3 + 0\dot{\xi}_4 = 0$$

$$0\dot{n}_{M1} + 0\dot{n}_{W1} + 0\dot{n}_{N1} + 0\dot{n}_{H2} + 0\dot{\xi}_1 + 1\dot{\xi}_2 + 0\dot{\xi}_3 - 0.5\dot{\xi}_4 = 0$$

$$0\dot{n}_{M1} + 0\dot{n}_{W1} + 0\dot{n}_{N1} - 1\dot{n}_{H2} + 3\dot{\xi}_1 + 1\dot{\xi}_2 - 3\dot{\xi}_3 + 0\dot{\xi}_4 = 0$$

$$0\dot{n}_{M1} + 0\dot{n}_{W1} + 1\dot{n}_{N1} + 0\dot{n}_{H2} + 0\dot{\xi}_1 + 0\dot{\xi}_2 - 1\dot{\xi}_3 + 0\dot{\xi}_4 = 0$$

$$0\dot{n}_{M1} + 0\dot{n}_{W1} + 0\dot{n}_{N1} + 0\dot{n}_{H2} + 0\dot{\xi}_1 + 0\dot{\xi}_2 + 2\dot{\xi}_3 - 1\dot{\xi}_4 = 0$$

$$0\dot{n}_{M1} + 0\dot{n}_{W1} + 0\dot{n}_{N1} + 0\dot{n}_{H2} + 0\dot{\xi}_1 + 0\dot{\xi}_2 + 0\dot{\xi}_3 + 0.5\dot{\xi}_4 = 90$$

As there are eight equations and eight unknowns, A will have eight rows and eight columns, b will have eight rows, and x will return the solutions to the eight unknown variables. Enter in the corresponding values below (expanding the number of rows or columns, if needed for new problems) and press run.

```
% initialize A and b to zeros for matrix and vector of the correct size for
% this problem
numEqns = 8;
A = zeros(numEqns);
b = zeros(numEqns,1);
nU2 = 90;
eqn = 1;
    A(eqn,1) = 1;
    A(eqn,5) = -1;
eqn = 2;
    A(eqn,2) = 1;
    A(eqn,5) = -1;
    A(eqn,6) = -1;
    A(eqn,8) = 0.5;
eqn = 3;
    A(eqn,5) = 1;
    A(eqn,6) = -1;
eqn = 4;
    A(eqn,6) = 1;
    A(eqn,8) = -0.5;
eqn = 5;
    A(eqn,4) = -1;
    A(eqn,5) = 3;
    A(eqn,6) = 1;
    A(eqn,7) = -3;
eqn = 6;
    A(eqn,3) = 1;
    A(eqn,7) = -1;
eqn = 7;
    A(eqn,7) = 2;
    A(eqn,8) = -1;
eqn = 8;
    A(eqn,8) = 0.5;
    b(eqn,1) = nU2;
A
```

```
A = 8×8
    1.0000         0         0         0   -1.0000         0         0         0
         0    1.0000         0         0   -1.0000   -1.0000         0    0.5000
         0         0         0         0    1.0000   -1.0000         0         0
         0         0         0         0         0    1.0000         0   -0.5000
         0         0         0   -1.0000    3.0000    1.0000   -3.0000         0
         0         0    1.0000         0         0         0   -1.0000         0
         0         0         0         0         0         0    2.0000   -1.0000
         0         0         0         0         0         0         0    0.5000
```

```
b
```

```
b = 8×1
     0
     0
     0
     0
     0
     0
     0
    90
```

```
x = A\b
```

```
x = 8×1
    90
    90
    90
    90
    90
    90
    90
   180
```

Further Practice and Interactive Coding Template for Homework

To get additional practice solving systems of linear equations, we have provided a MATLAB live script titled Systems_of_Linear_Equations.mlx, with the same worked example as above and an interactive example. The corresponding solution to the interactive example is available in Systems_of_Linear_Equations_sol.mlx. We also have created an explanatory youtube video: Solving Systems of Linear Equations Using a MATLAB Live Script

You are encouraged to edit Systems_of_Linear_Equations.mlx as an interactive coding template for solving homework problems.