ECE 569 Lab 3 Tutorial

If you are new to MATLAB, this tutorial will help you with the basic commands you will need in order to complete this assignment.

```
clear all; % delete variables in current Workspace
close all; % close all figures (if any are open)
clc;       % clear the Command Window
```

Vectors and Matrices

MATLAB supports both row vectors and column vectors. Here are some examples:

```
row_vector_1 = zeros(1,6)   % 1 row, 6 columns
```

```
row_vector_1 = 1×6
     0     0     0     0     0     0
```

```
row_vector_2 = 1:10         % 1,2,3,4,...,9,10
```

```
row_vector_2 = 1×10
     1     2     3     4     5     6     7     8     9    10
```

```


column_vector_1 = ones(5,1) % 5 rows, 1 column
```

```
column_vector_1 = 5×1
     1
     1
     1
     1
     1
```

```
column_vector_2 = (3:2:13)' % the ' is the transpose operator
```

```
column_vector_2 = 6×1
     3
     5
     7
     9
    11
    13
```

Note that you can suppress output by using the semicolon ; at the end of the line.

```
x_data = rand(3,1); % remove the ; to see the output
```

To access an element inside a vector, use `()` for indexing. Note that in MATLAB, indexing starts at 1.

```
row_vector_1(2) = 17            % index 2
```

```
row_vector_1 = 1×6
     0    17     0     0     0     0
```

```
row_vector_1(end) = 100         % end gives final index
```

```
row_vector_1 = 1×6
```

```
     0    17     0     0     0   100
```

```
column_vector_1(end-1) = 2*3    % end-1 works too!
```

```
column_vector_1 = 5×1
     1
     1
     1
     6
     1
```

You can also define vectors using brackets [ ]

```
small_primes = [2 3 5 7 11 13]  % row vector
```

```
small_primes = 1×6
     2     3     5     7    11    13
```

```
gas_prices = [3.81; 3.99; 4.25] % column vector
```

```
gas_prices = 3×1
    3.8100
    3.9900
    4.2500
```

Matrices are similarly defined and accessed.

```
R = ones(3,3)
```

```
R = 3×3
     1     1     1
     1     1     1
     1     1     1
```

```
I = eye(3)
```

```
I = 3×3
     1     0     0
     0     1     0
     0     0     1
```

```
M = [1 2 3; 4 5 6; 7 8 9]
```

```
M = 3×3
     1     2     3
     4     5     6
     7     8     9
```

```

% Change the (2,3) element of R
R(2,3) = 200
```

```
R = 3×3
     1     1     1
     1     1   200
     1     1     1
```

```

% Get the 3rd column of R.
```

```
% Think: Every row, 3rd column
R(:,3)
```

```
ans = 3×1
     1
   200
     1
```

```
% Get the first row of M
% Think: first row, every column
M(1,:)
```

```
ans = 1×3
     1     2     3
```

```
% Modify a section of a matrix
M(2:3,1:2) = -1*[11 12; 13 14]
```

```
M = 3×3
     1     2     3
   -11   -12     6
   -13   -14     9
```

```
% Transpose a matrix
M'
```

```
ans = 3×3
     1   -11   -13
     2   -12   -14
     3     6     9
```

You can construct a matrix from column vectors (and also row vectors).

```
c1 = [10; 20; 30];
c2 = [40; 50; 60];
C = [c1 c2]
```

```
C = 3×2
    10    40
    20    50
    30    60
```

To check the size of a matrix of vector, use `size()`

```
size(C)
```

```
ans = 1×2
     3     2
```

```
size(C,1) % number of rows
```

```
ans = 3
```

```
size(C,2) % number of columns
```

```
ans = 2
```

What about a list of matrices? Sometimes, we want to use a single variable to represent a bunch of different matrices of the same size. In this example, we have 5 matrices, $A_1 \ldots A_5$ each of which is a 2x2 matrix.

```
A = zeros(2,2,5);
A(:,:,1) = ones(2,2);
A(:,:,2) = rand(2,2);
A(:,:,3) = [1 2; 3 4];
A(:,:,4) = A(:,:,1) + A(:,:,3);
A
```

```
A =
A(:,:,1) =

     1     1
     1     1


A(:,:,2) =

    0.1576    0.9572
    0.9706    0.4854


A(:,:,3) =

     1     2
     3     4


A(:,:,4) =

     2     3
     4     5


A(:,:,5) =

     0     0
     0     0
```

Matrix multiplication, scalar multiplication, addition, subtraction work as you would expect, but MATLAB also allows for element-wise operators.

```
x = 1:4;
5*x
```

```
ans = 1×4
     5    10    15    20
```

```
2+x
```

```
ans = 1×4
     3     4     5     6
```

```
x.^2 % square each element
```

```
ans = 1×4
     1     4     9    16
```

```
exp(x) % e^x1 e^x2 ...
```

```
ans = 1×4
    2.7183    7.3891   20.0855   54.5982
```

```
sin(x) % sin(x1) sin(x2) ...
```

```
ans = 1×4
    0.8415    0.9093    0.1411   -0.7568
```

```
A = magic(3);
B = diag([1 2 3])
```

```
B = 3×3
     1     0     0
     0     2     0
     0     0     3
```

```
A*B    % matrix multiplication
```

```
ans = 3×3
     8     2    18
     3    10    21
     4    18     6
```

```
A.*B   % element-wise multiplcation
```

```
ans = 3×3
     8     0     0
     0    10     0
     0     0     6
```

Be careful with functions with matrices. Sometimes they are applied elementwise and sometimes they are applied to the entire matrix. If you don't know, use the `help` command in the Command Window

```
exp(A)   % element-wise exponential
```

```
ans = 3×3
10^3 ×
    2.9810    0.0027    0.4034
    0.0201    0.1484    1.0966
    0.0546    8.1031    0.0074
```

```
expm(A)  % matrix exponential
```

```
ans = 3×3
10^6 ×
    1.0898    1.0896    1.0897
    1.0896    1.0897    1.0897
    1.0896    1.0897    1.0897
```

```
help expm
```

```
 expm  Matrix exponential.
    expm(A) is the matrix exponential of A and is computed using
```

```
a scaling and squaring algorithm with a Pade approximation.

Although it is not computed this way, if A has a full set
of eigenvectors V with corresponding eigenvalues D then
[V,D] = EIG(A) and expm(A) = V*diag(exp(diag(D)))/V.

EXP(A) computes the exponential of A element-by-element.

See also expmv, logm, sqrtm, funm.

Documentation for expm
Other uses of expm
```

Plotting and Subplots

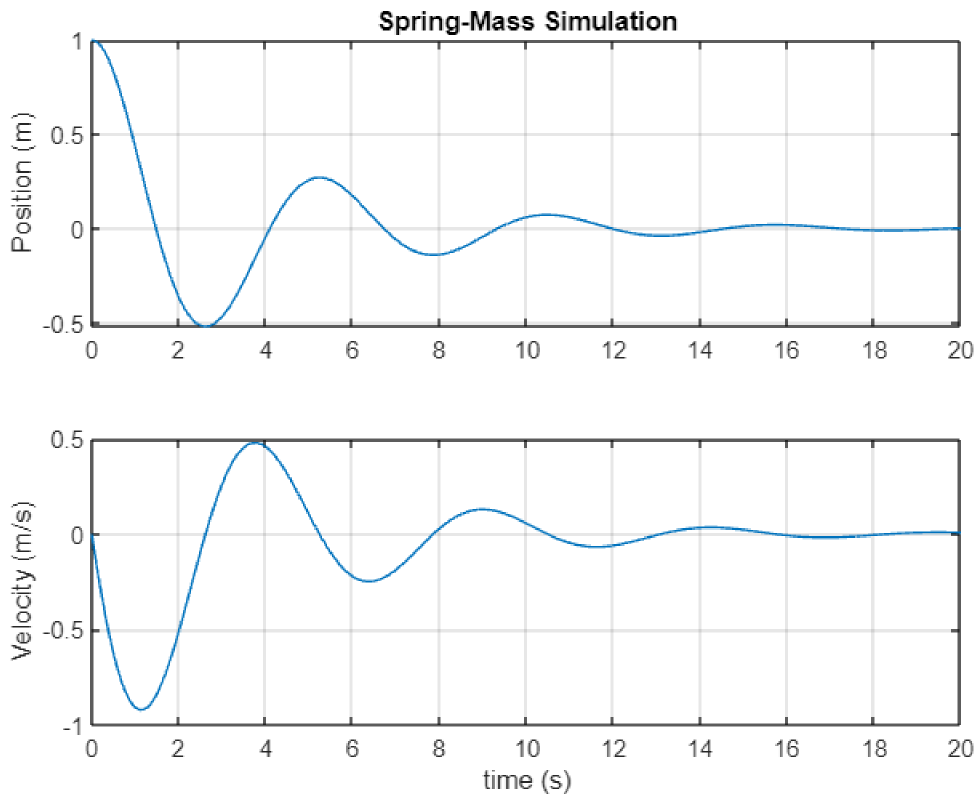
We can plot two vectors (x vector, y vector) using the plot command. In this example, we simulate a spring-mass system with damping using a state space model (simulating a model is not required on this homework!)

```
% model coefficients
k = 3;
b = 1;
m = 2;

% state space model
A = [0 1; -k/m -b/m];
B = [0; 0];
C = eye(2);
D = 0;
sys = ss(A,B,C,D);

% time vector
t = (0:0.1:20)';

% initial condition
x0 = [1; 0];

% simulation (input u = 0*t)
[y,t] = lsim(sys,0*t,t,x0);
q = y(:,1); % position
v = y(:,2); % velocity
```

Now we have two vectors q and v which we would like to plot as functions of time. We need to use `subplot` to select which part of the figure to graph. We first tell subplot that we want the figures arranged in a (2,1) column vector, and then specify the index. If you wanted to plot 4 signals, then you would have the command `subplot(4,1,1)` and then `subplot(4,1,2),` etc. Sometimes you want to plot a row vector. That is not a problem either for the plot function.

```
% plotting
figure()
subplot(2,1,1); plot(t,q); grid on; ylabel('Position (m)');
title('Spring-Mass Simulation')
```

```
subplot(2,1,2); plot(t,v); grid on; ylabel('Velocity (m/s)');
xlabel('time (s)');
```



Loops

Best seen with an example or two.

```
N = 10;
A = zeros(3,3,N);

for i=1:N
    A(:,:,i) = i * ones(3,3);
end
A
```

```
A =
A(:,:,1) =

     1     1     1
     1     1     1
     1     1     1


A(:,:,2) =

     2     2     2
     2     2     2
     2     2     2
```

```
A(:,:,3) =

     3     3     3
     3     3     3
     3     3     3


A(:,:,4) =

     4     4     4
     4     4     4
     4     4     4


A(:,:,5) =

     5     5     5
     5     5     5
     5     5     5


A(:,:,6) =

     6     6     6
     6     6     6
     6     6     6


A(:,:,7) =

     7     7     7
     7     7     7
     7     7     7


A(:,:,8) =

     8     8     8
     8     8     8
     8     8     8


A(:,:,9) =

     9     9     9
     9     9     9
     9     9     9


A(:,:,10) =

    10    10    10
    10    10    10
    10    10    10
```

```
% compute row sums of A_i
A_first_row_sums = zeros(N,1);
for i=1:N
    Ai = A(:,:,i);  % get the ith matrix
    A_first_row_sums(i) = sum(Ai(1,:));
```

```
end
A_first_row_sums'
```

```
ans = 1×10
     3     6     9    12    15    18    21    24    27    30
```

If ElseIf Else

```
N = 10;
A = zeros(3,3,N);

for i=1:N
    if mod(i,3) == 0
        % i = 3,6,9,...
        A(:,:,i) = 3*ones(3,3);
    elseif mod(i,3) == 1
        % i = 1,4,7,...
        A(:,:,i) = ones(3,3);
    else
        A(:,:,i) = 2*ones(3,3);
    end
end
A
```

```
A = 
A(:,:,1) =

     1     1     1
     1     1     1
     1     1     1


A(:,:,2) =

     2     2     2
     2     2     2
     2     2     2


A(:,:,3) =

     3     3     3
     3     3     3
     3     3     3


A(:,:,4) =

     1     1     1
     1     1     1
     1     1     1


A(:,:,5) =

     2     2     2
     2     2     2
     2     2     2
```

```
A(:,:,6) =

     3     3     3
     3     3     3
     3     3     3


A(:,:,7) =

     1     1     1
     1     1     1
     1     1     1


A(:,:,8) =

     2     2     2
     2     2     2
     2     2     2


A(:,:,9) =

     3     3     3
     3     3     3
     3     3     3


A(:,:,10) =

     1     1     1
     1     1     1
     1     1     1
```

Inline Functions

You can create your own one-line functions. The syntax is a little strange, but not difficult with practice.

```
my_sum = @(x,y) x+y;
z = my_sum(3,4)
```

```
z = 7
```

```

my_matrix = @(x) [0 x 0; 0 0 x; x 0 0];
A = my_matrix(7)
```

```
A = 3×3
     0     7     0
     0     0     7
     7     0     0
```

Functions

For functions that take multiple lines, you can either put them into their own .m file (with the same name as the function itself) or put them at the bottom of your live script.

```
[s,d] = Add_Sub(5,7)
```

```
s = 12
d = -2
```

```
s1 = My_Square(12)
```

```
s1 = 144
```

```
s2 = My_Square(-3) % ALWAYS test your functions!
```

```
s2 = 0
```

```
function [the_sum, the_diff] = Add_Sub(x,y)
    the_sum = x+y;
    the_diff = x-y;
end

function y = My_Square(n)
total = 0;
for i=1:n
    total = total + n;
end
y = total;
end
```