**Control & Instrumentation Lab, Autumn 2020-21**

**Session 1: Preliminaries**

At the end of the session, the students shall be able to

1. carry out basic mathematical operations
2. define and manipulate vectors and matrices
   1. assign variables, take the sum and find the minimum and maximum entries
   2. access suitable entries and sub-vectors & matrices efficiently
   3. create special class of matrices (identity, zero, diagonal, etc.) efficiently
   4. create vectors efficiently using the colon operator
   5. compute algebraic operations, transpose, eigenvalues and eigenvectors and inverse of matrices
3. become familiar with ‘for’ and ‘while’ loops, ‘if-else’ blocks, user defined functions, and
4. create plots with appropriate thickness, label, axes, legends, colors, etc.

**Practice Problems and Solutions**

1. **Basic Mathematical Operations**
   1. Enter the following into MATLAB. Repeat after you enter ‘format long’

pi

sqrt(2)

exp(1)

format long

pi

sqrt(2)

exp(1)

* 1. If you want to enter 1020 in MATLAB, do you use 10e20 or 1e20? If you want to enter 3.54 × 10-5 in MATLAB, do you use 354e-5, 3.54e-5, 0.354e-5 or -3.54e5?
  2. Using the appropriate mathematical functions in MATLAB, calculate the following mathematical expressions: *e*2, tan(1), sin–1(sin(5)), sin (sin–1(5)), ln(*e*-2 + 3*j*).
  3. If *z* = 5.32 – 3.24*j*, demonstrate that  where  is the complex conjugate of *z*; ; , and  where  and  are the real and imaginary parts of *z*, respectively.
  4. Using MATLAB, what are the absolute and relative errors of 2.718 as an approximation to *e*?

1. **Vector Operations**
   1. Enter the MATLAB commands required to construct the row vector.
   2. Enter the MATLAB code required to construct the column vector  using both the semicolon and the transpose operator.
   3. Evaluate u+v and the inner product and element-wise multiplication of u and v as defined above. Subtract 1 from each entry of the vector u.
   4. Create and assign following row vectors efficiently (using : operator) in MATLAB:
      1. The row vector ,
      2. The row vector , and
      3. The row vector.
   5. Create a row vector containing 50 equally spaced points from 1 to 10 inclusive.
   6. How many entries are there in the vector 1:pi:exp(10)? (use the function ‘length’)
   7. Use MATLAB to find the minimum value and the index of the minimum element of a row vector containing 100 random entries from the interval [0, 1].
   8. Explain in English what occurs here:

>> linspace(0, pi, 5) .\* [0 1 0 0 1]

### Calculate the sum 0.12 + 0.22 + 0.32 + ⋅⋅⋅ + 9.92 + 102 using the appropriate MATLAB vector constructor, element-wise exponentiation and the MATLAB sum function.

1. **Matrix Operations**
   1. Create a 4 × 4 matrix of all ones and a 4 × 4 identity matrix.
   2. Efficiently create and assign to **M** the diagonal matrix

.

* 1. Find the transpose of the matrix

>> M1 = [1 2 3; 4 5 6; 3 8 9];

and assign it to the variable M2. Add the transpose of M1 with itself.

* 1. Divide each entry of the matrix M3 = [3.2 -4.5; 7.6 8.1] by the maximum entry.
  2. Given M4 = [0.5 0.2; 0.4 0.7], show that **M**42 and **M**4**M**4 return the same matrix by calculating both in MATLAB.
  3. Consider the Matrix

>> M5 = [1 1 1 1 1 1 1 1; -2 -1 0 1 2 3 4 5; 4 1 0 1 4 9 16 25];

What is the entry in the 3rd row and 7th column?

* 1. Extract the 2nd row and 7th column of M5 and assign these to vectors **v**1 and **v**2, respectively?
  2. Assuming that the matrix is of the appropriate size, describe in one sentence what the following operations perform:

>> M(2, :) = 3.2\*M(2,:);

>> M(3, :) = M(3,:) + 0.527\*M(1,:);

* 1. Solve the system of linear equations described by solving **Mx** = **b**



Use the command x = M \ b and verify.

1. **Conditionals, Loops and User Defined Functions**
   1. Add all the elements of the Matrix M5 using for loops.
   2. Create a while loop that finds the first positive integer *k* such that 1/*k* < /1000.
   3. The sincfunction is defined as  . Write a function mysinc that conditionally returns 1 if the argument is x == 0 and sin(x)/x otherwise. Enter your function here and run the following tests:

function [y] = mysinc(x)

% Enter your implementation here

end

>> mysinc(0)

>> mysinc(2)

>> sin(2)/2

* 1. Implement and save the following two functions in MATLAB.

Note that mfun2 is the derivative of the function mfun1. Execute the following

mfun1(0:3) and mfun2(0:3). In other words, the functions must work for

vector inputs.

* 1. Write a function to approximately compute the derivative of a given function using the central finite difference approximation. In particular, create a function derivative\_central\_approx that takes three arguments: f, x and h and would assign to the return value

You may test your function as follows. Set h = 1e-5, and evaluate

derivative\_central\_approx (@sin,1,h) and (sin(1 + h) - sin(1 - h))/(2\*h), and

derivative\_central\_approx (@mfun1, 1, h) and mfun2(1).

1. **Plots**

General instruction: To export an image from the MATLAB *Figure* dialog, select File→Save As... and in the *Save As* dialog, select the *Save as type: Portable Network Graphics file (\*.png)* and give the file an appropriate name. You may wish to change the directory to the *Desktop*. Next, in Word, right click on the existing image in Figure 1 and select Change Picture... and choose the appropriate file from the *Insert Picture* dialog.

* 1. Create a vector of 50 points going from 0 to 10. Plot the function sin(*x*) + 1 for these 50 points where the line is cyan and dashed (that is, use the option 'c--').
     1. If you plot the same function as above with the option 'go-', what will it look like?
     2. What additional commands would you use to give the above plot the title “The System Response”, the legend “sin(x) + 1”, to give the background a grid of lines, and to change the range on the y-axis to [-1, 2]?
  2. Create a vector of 50 points going from -10 to 10. Plot the functions **mfun1** and **mfun2** (from problem 5.2) on the same figure for these 50 points with the line for **mfun1** is thick, red and dashed and the line for **mfun2** is of normal width, black and solid. Place appropriate legends. Give the title to be your roll no.