QUICK INTRODUCTION TO MATLAB PART I

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General Remarks

This worksheet is designed for use with MATLAB version 6.5 or later. Once you have MATLAB running on your machine, you get MATLAB to do things for you by typing commands at the prompt sign ">>".

There are various forms of help available. Typing
`helpwin`, **`helpdesk`**, or **`demo`** opens an interactive help window
`help <function_name>` lists the description of <function_name> in the command window

`diary on`, **`diary off`** - record all activities on the command window into a file named "**diary**" (e.g. for assignments)
`diary <filename>` - save your session in a file named "**<filename>**". If the file already exists, the new listing is appended.

Matrices

The basic object in MATLAB is a matrix (hence the name, MATtrix LABoratory). The entries of a matrix are complex numbers.
There is no limitation on the size of the matrix (number of rows and number of columns).
Scalars are treated as 1x1 matrices.

To type a matrix into MATLAB

- use square brackets "[" and "]"
- separate elements in a row with commas "," or spaces " "
- use a semicolon ";" to separate rows.

For example, type

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

```
ans =
      1     2     3
      4     5     6
      7     8     9
```

```
[2+3*i; pi; exp(1)]
```

```
ans =
    2.0000 + 3.0000i
     3.1416
    2.7183
```

All computations are performed in double precision. The **`format`** commands switch between different output formats:

```
format short; pi % 4 decimal digits

ans =
       3.1416

format long;  pi % 14 decimal digits
format short e; pi % 4 decimals in exponential nonation
format long e; pi % 14 decimals in exponential notation

ans =
       3.14159265358979
ans =
       3.1416e+000
ans =
       3.141592653589793e+000
```

Alternatively, you can tell **`num2str`** how many digits to display

```
num2str(pi, 3)

ans =
       3.14
```

MATLAB has several ways to generate simple matrices (need to specify the size)

- zeros - matrix with all elements equal to zero
- ones - matrix with all elements equal to one
- eye – identity matrix
- rand – matrix with uniformly distributed random elements
- randn - matrix with normally distributed random elements

Examples to try:

```
zeros(2,3), ones(2,2), eye(3)

ans =
     0     0     0
     0     0     0
ans =
     1     1
     1     1
ans =
    1     0     0
    0     1     0
    0     0     1
```

Variables

Variables in Matlab are named objects that are assigned using the equal sign "=". They may contain upper and lowercase letters,
any number of "_" characters and numerals, but cannot start with a numeral.

- names and types of variables do not have to be declared *apriori*.
- names of variables should not overlap with MATLAB keywords, function names and command names
- Scalar variables can be later extended into vectors and matrices

Examples of valid MATLAB variable assignments:

```
a = 1
ind = [1 3 5 7]
Output_Type1 = v*Q*v'
name='John Smith'
```

The following are **bad** choices for variable names

2for1 = 'yes'
end = 1
sin = 10
i = 2

- **`clear <variable_name>`** - delete the value of <variable_name> from the current working space
- **`clear all`** - clear values of all variables
- **`clc`** - clear the command window and move the cursor to the top

Common Operators

- Semicolon ";" is used to assign a variable without getting an echo from MATLAB.
- Comma "," separates different commands on the same line, the result is printed for each command
- Colon ":" generates an ordered set of numbers
- Three periods "…" split a long command into several lines.
- Comment sign "%" makes MATLAB ignore the whole line *after* the sign, hence is used for comments.

Try the following:

```
a = 2
```

```
b = 3;
c = a+b;
d = c/2;
c, d
who  % Lists all variables defined so far
whos
clear  % Clears all previously defined variables
f = 1:5;
who
```

Arithmetic Operations

- **"+", "-", "*", "/"** – conventional operators for addition, substraction, multiplication and division
- **"\\"** – inverse division (3\2 = 2/3 = 0.6666)
- **"^"** – power operator

Type the following

```
r = 10;
vol = 4*pi ...
      *r^3/3;
r,vol

r =
    10
vol =
       4.1888e+003
```

- **".*", "./"** – multiplication and division between the elements of two matrices of the same dimension
- **".^" –** power operation for each element of the matrix

Try the following commands

```
A = [1 2;3 4], B=2*ones(2)
A.^2, A.*B %Note that these are not the same as A^2 and A*B

A =
     1     2
     3     4
B =
     2     2
     2     2
ans =
     1     4
     9    16
ans =
     2     4
     6     8
```

Vectors

A vector is a one-dimensional array, which is a matrix consisting of one column (**column vectors**) or of one row (**row-vectors**).
MATLAB code is designed to handle matrices (in particular vectors) in an optimal way, and it contains an extensive list of operations
with vectors/matrices. Let's start learing the most elementary ones.

- Consider the row vector **x** and the column vector **y** as follows

```
x  = [ 0, 0.5, 1, 1.5, 2] , y=[0; 2; 4; 3; 1]

x =
         0    0.5000    1.0000    1.5000    2.0000
y =
     0
     2
     4
     3
     1
```

- To access individual elements, try

```
x(2), y(3)

ans =
    0.5000
ans =
     4

x(6)

??? Index exceeds matrix dimensions.

y(0)

??? Subscript indices must either be real positive integers or
logicals.

x(2:4) % reduces the dimension of x by retaining only the elements
ranked 2 thru 4
y(end-2:end) % reduce the dimension of y and retain only the last
```

```
three elements

ans =
    0.5000    1.0000    1.5000
ans =
     4
     3
     1
```

- One can extract rows and columns from a given matrix. For example

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

a =
     1     2     3
     4     5     6
     7     8     9

a(:,2), a(3,:)

ans =
     2
     5
     8
ans =
     7     8     9
```

- Conversely, one can generate new matrices by concatenating old vectors/matrices:

```
b = [a -a; a(3,:) zeros(1,3)]

b =
     1     2     3    -1    -2    -3
     4     5     6    -4    -5    -6
     7     8     9    -7    -8    -9
     7     8     9     0     0     0
```

- To list all the elements of a matrix and form a *row vector*, type

```
a(:)'

ans =
     1     4     7     2     5     8     3     6     9
```

Note that the listing starts with the elements on the first column, then the second and the third!

- An equally-spaced vector x can be defined using the colon operator **":"**

```
x = 0:0.5:2 % (first element, step size, last element)

x =
         0    0.5000    1.0000    1.5000    2.0000
```

Another example is

```
t = 0:.3:2*pi

t =
  Columns 1 through 7
         0    0.3000    0.6000    0.9000    1.2000    1.5000    1.8000
  Columns 8 through 14
    2.1000    2.4000    2.7000    3.0000    3.3000    3.6000    3.9000
  Columns 15 through 21
    4.2000    4.5000    4.8000    5.1000    5.4000    5.7000    6.0000
```

- Another way to generate an equally-spaced vector is using the 'function' **"linspace"**.

```
x=linspace(0,0.25,5) % linspace(first element, last element, number of elements)

x =
         0    0.0625    0.1250    0.1875    0.2500
```

Pointwise multiplication, division and pointwise power:

```
x=[1,2,3]; y=[0,2,-1];
x.*y % multiplies pointwise two vectors of the same size
x./y % no loops required for accessing individual elements

ans =
     0     4    -3
Warning: Divide by zero.
(Type "warning off MATLAB:divideByZero" to suppress this warning.)
ans =
   Inf     1    -3

x.^2
x.^y % same as x(k)^y(k) for every k
3.^x % same as 3^x(k); the output has same size as x

ans =
     1     4     9
```

```
ans =
    1.0000    4.0000    0.3333
ans =
     3     9    27
```

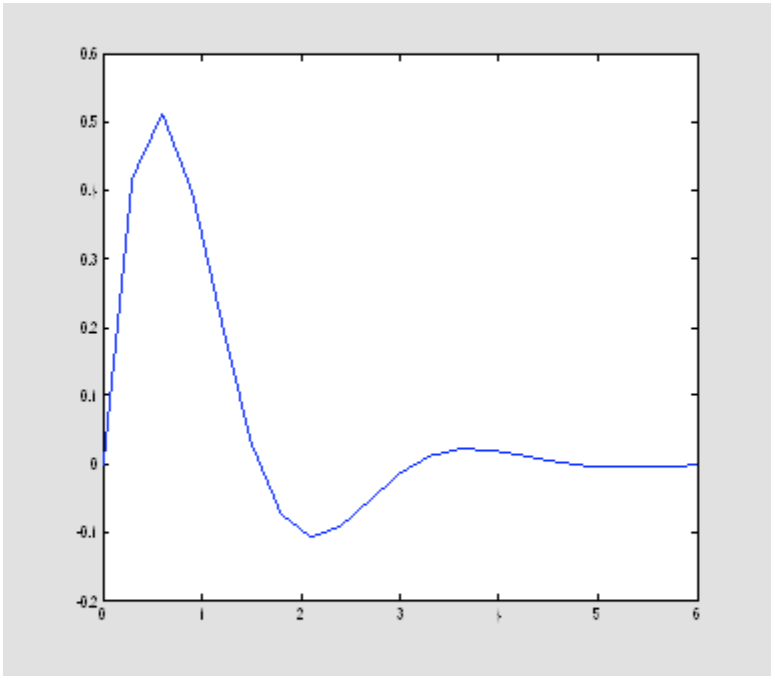
These operation are one of the main advantages of MATLAB, since they do not require involving loops.

Basic Graphics

The most efficient way of representing the outcome of a numerical computation is to plot the data.

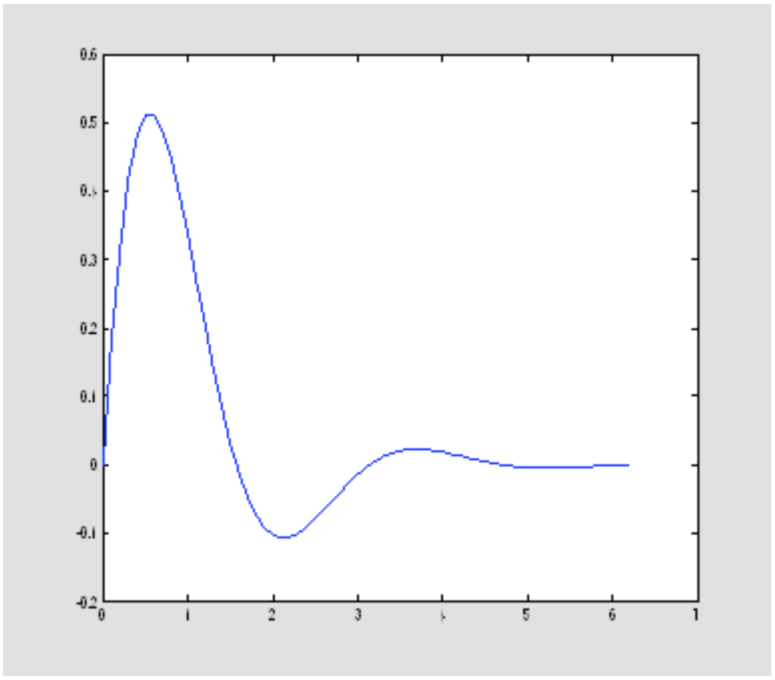
Here are a few examples of MATLAB plots.

```
x = 0 : 0.3 : 2*pi; % low resolution
y = exp(-x).*sin(2*x);
plot(x,y)
```



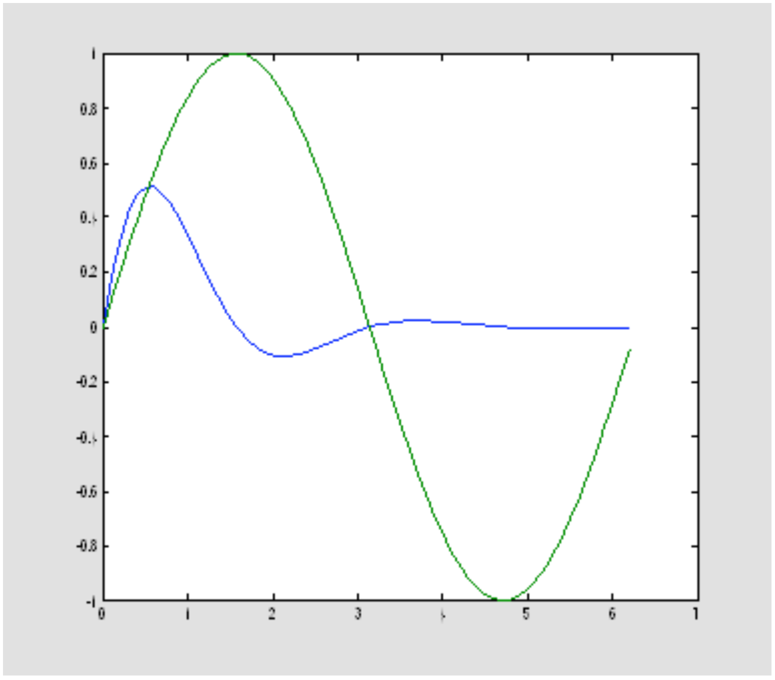
A better resolution is obtained below

```
x = 0 : 0.1 : 2*pi; % higher resolution
y = exp(-x).*sin(2*x);
plot(x,y)
```



One can plot several curves at the same time

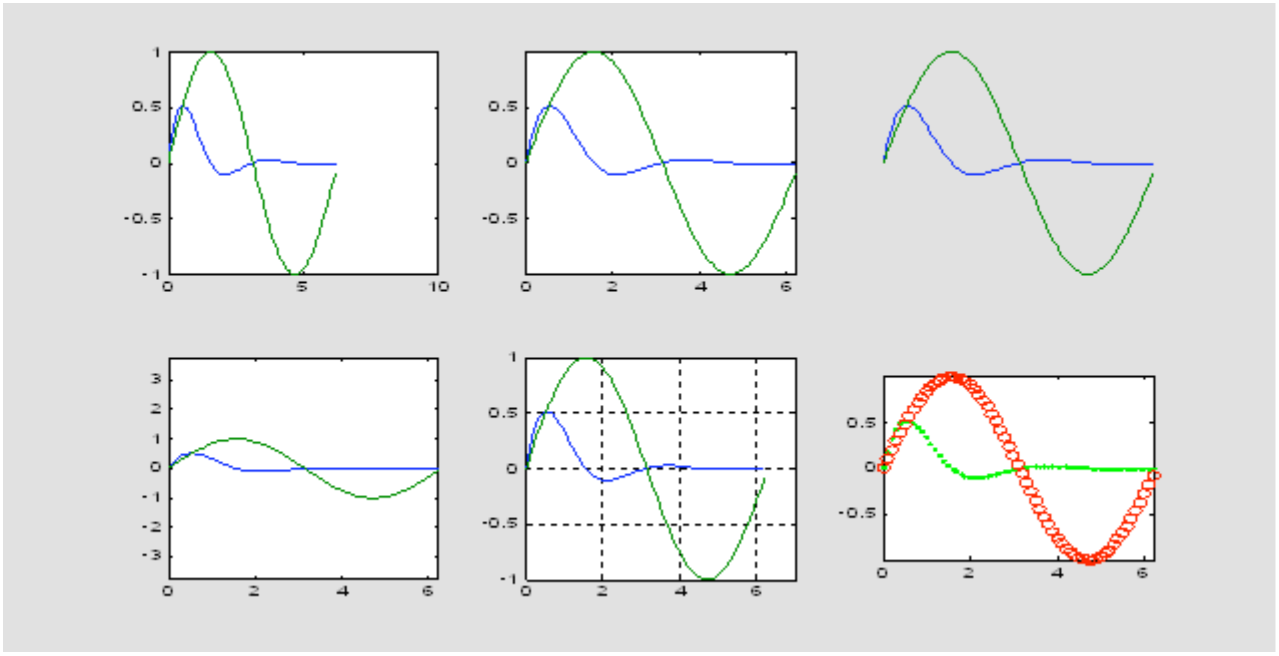
```
plot(x,y, x,sin(x)) % The two curves appear in distinct colors; both
use the same scale
```



MATLAB offers many formatting options for such plots, e.g.

```
x = 0 : 0.1 : 2*pi;
```

```
subplot(2,3,1); plot(x,y, x,sin(x)), axis auto
subplot(2,3,2); plot(x,y, x,sin(x)), axis tight
subplot(2,3,3); plot(x,y, x,sin(x)), axis tight, axis off
subplot(2,3,4); plot(x,y, x,sin(x)), axis equal
subplot(2,3,5); plot(x,y, x,sin(x)), axis([0 7 -1 1]), grid on
subplot(2,3,6); plot(x,y,'g.', x,sin(x),'ro'), axis tight, axis square
```



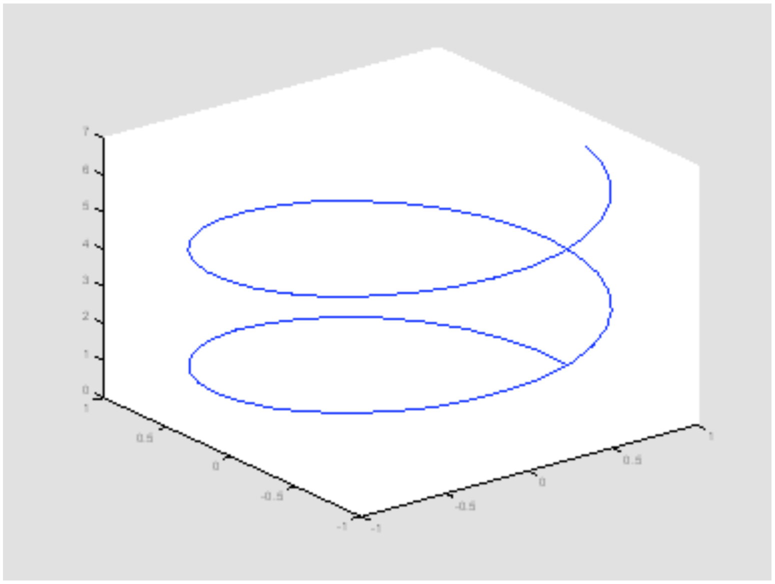
- The command **`subplot(m,n,p)`** divides the window into **`mxn`** regions (**`m`** rows and **`n`** columns) and chooses
the **`p`**th plot for drawing into. The numbering of the regions is from left to right, then down, as you read text.

- There are numerous plot types for the data marks
  - **`"."`** – point
  - **`"+"`** – plus
  - **`"*"`** – star
  - **`"d"`** – diamond
  - **`"o"`** – circle
  - **`"p"`** – pentagon
  - **`"s"`** – square
  - **`"^"`** – triangle
  - **`"x"`** – x-mark
- Line types and line colors are, among others,
  - **`"-"`** – solid line
  - **`"--"`** – dashed line

- **":"** – dotted line
- **"-."** – dash-dotted line
- **"r"** – red
- **"y"** – yellow
- **"m"** – magenta
- **"c"** – cyan
- **"g"** – green
- **"b"** – blue
- **"w"** – white
- **"k"** – black

- A 3D plot is obtained with the command **`plot3`**.

```
t=0:.1:2*pi;
plot3(cos(2*t), sin(2*t),t)
```



- You can rotate the 3D plot by invoking the command

```
rotate3d
```

Simply click the mouse button on the plot and drag. You will change in this way the viewing angle.
Releasing the mouse button redraws the data. Type **`rotate3d`** again to turn off this feature.

Operations with figures

- **`figure`** – opens a new graphic window, numbered consecutively from the previous window
- **`figure(n)`** – makes an existing graphic window (n) the current window; (all graphic commands will apply

the current window)

- **`pause`** – holds up execution of the script until the user presses a key
- **`pause(s)`** – holds up the execution of the script for s seconds
- **`close(n)`** – closes the graphic window (n)
- **`close all`** – closes all graphic windows
- **`clf`** – clears everything inside the graphic window
- **`cla`** clears the plotted curves and redraws the axes
- **`figure('Position',[pix,piy,pwx,pwy])`** – sets the size and shape of the current window
  - pix,piy – horizontal and vertical cordinates of the left bottom corner of the window
  - pwx, pwy – number of pixels in the width and height of the window
  - defalut – figure('Position',[232,258,560,420])
- **`get(gcf)`** – displays the properties of the current figure, e.g. size, location, color map, and many others
- **`set(gcf, 'PropertyName', PropertyArray)`** – changes the property "PropertyName" of the current window according to the data in PropertyArray, e.g.

```
set(gcf, 'DefaultTextColor', 'blue')
set(gcf,'PaperPosition',[0.25 2.5 4 3]);
```

- **`hold on`** – superposes several plots on the same graph, even if another script is executed (default is hold off)
- **`hold off`** – recommeded to be used at the end of the script whenever hold on has been used in the script.

Labels and titles

- **`xlabel('x-axis')`** – the string 'x-axis' is printed as a label for the x-coordinate
- **`ylabel('y-axis')`** – the string 'y-axis' is printed as a label for the y-coordinate
- **`title("The graph of y=f(x)')`** – the string 'The graph of y=f(x)' is printed as a title of the plot
- **`legend('y=f(x)')` –** the string 'y=f(x)' is printed In a small sub-window showing the line type or data marks
- **`text(x,y,'TextBody')` –** the string 'TextBody' is printed on the figure, starting at the absolute coordinate (x,y) pixels.

Font size

- **`plot(x,y,'-', 'linewidth',3)`** – the defalut line width is 0.5
- **`xlabel('x-axis','fontsize',14)`** – the default font size is 12pt