# Introduction to MATLAB

**Lecture-1**

# Objectives

- Background of MATLAB
- Advantages and disadvantages
- Applications
- Basic commands, syntax
- Introduction to decimal places, rounding, significant figures
- Solve problems using different mathematical methods

# Background of MATLAB

- It stands for matrix laboratory
- It is a technical programming language
- Superior to other language such as C, FORTRAN
- A special purpose of computer program optimized to perform engineering and scientific calculations
- It provides very extensive library of predefined functions to make technical programming task easier and efficient.

# Advantages and Disadvantages of MATLAB

**Advantages:**

- **Easy to use**
- **Independent platform**
- **Pre-defined functions**
- **Device independent plotting**
- **Graphical user interface**

**Disadvantages:**

- **Computing speed is slow**

# Applications

- **Technical computing**
- **Control design**
- **Communications design**
- **Test and Measurement**
- **Image processing**
- **Signal processing**
- **Chemical Industry**
- **Financial modelling and Analysis**

# Basic commands and Syntax

Simple computation may be carried out in the **Command Window** by entering an instruction at the prompt. Commands and names are case sensitive.

# **Used fixed constant** (Example-pi())

# **Built-in Functions**

Mathematical functions are available with commonly used name. Note the following change:

log() natural logarithm(ln), log10() log base 10

Percent (%) sign is used to write comments.

Semicolon (;) at the end of command suppress the output.

# **Matrices**

All variables in MATLAB are treated as matrices or arrays.

**A row vector may be entered as**

```
>> x=[1 2  3] or  x=[1,2,3]
Output x =
      1    2    3
```

**A column vector may be entered as**

>> y = [4; 5; 6] or y = [4 5 6]’

Output y =

4

5

6

# **Semicolons** are used to separate the rows of a matrix.

**An example of a 3-by-4 matrix is** B = [1 2 3 4; 5 6 7 8; 9 10 11 12]

# **Using colon (:)**

**Example- x=1:5** %Generates a vector with interval of 1 from $1 \text{ to } \leq 5$

# **Use linspace**

**Example-linspace (a, b, n)** % generate *n* values in [a, b] with equal length

**x2 = linspace(1,2.5,4)**

**Output x2 =**

**1 1.5 2 2.5**

## Controlling number of digits

The fixed-point numbers:

| | |
|---|---|
| format short | displays 5 digits |
| format long | displays 16 digits |

The floating-point representation:

| | |
|---|---|
| format short e | gives 5 digits plus the exponent |
| format long e | gives 16 digits plus the exponent |

The combined format (fixed point or floating depending on the magnitude of the number)

format short g

format long g

**Printing command in MATLAB**

1. By typing the name of a variable (displays the output indicating variable name).

Example- write the new script then save as ".m" file.

```
clear
>>A=[1, 2.25  4.56];
>> A
A =
   1.0000    2.2500    4.5600
```

2. By using "disp" built in function. This displays output without variable name.

```
>>disp(A)
   1.0000    2.2500    4.5600
```

3. By using "**fprintf** " function

**Syntax:** fprintf(formatSpec, $A_1$, $A_2$, . . . , $A_3$)

**Printing command in MATLAB**

Example-

```
>>clear
>> x=0:0.5:2;
>> y=sin(x);
>>fprintf('%6s %12s\n','x','sin(x)’)
>> fprintf(‘%4.2f %8.6f\n’,x,y)
     x        sin(x)
  0.00    0.000000
  0.50    0.479426
  1.00    0.841471
  1.50    0.997495
  2.00    0.909297
```

# Plotting command in MATLAB

**2-D Plot**

plot(y) x = 1 : n (if not supplied)

plot(x,y) x, y are vectors

plot($x_1$, $y_1$, . . . .. , $x_{n,}Y_n$)

title('plot title')

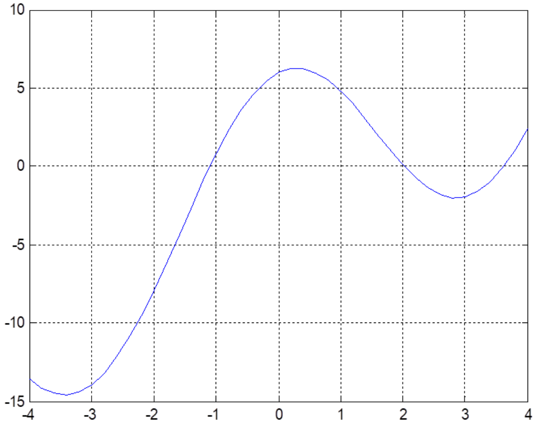
xlabel('label for x-axis')

ylabel('label for y-axis')

$\boxed{\begin{array}{ll} \text{grid on} & \text{grid off} \\ \text{grid (toggles)} & \\ \text{hold on} & \text{hold off} \\ \text{box on} & \end{array}}$

**Example #**. Plot the function $y = 7\cos x + 2x - 1$ in [-4,4].

```
>> x= -4:0.2:4;
>> y=7*cos(x)+2*x-1;
>> plot(x,y);grid on
```



## Plotting command in MATLAB

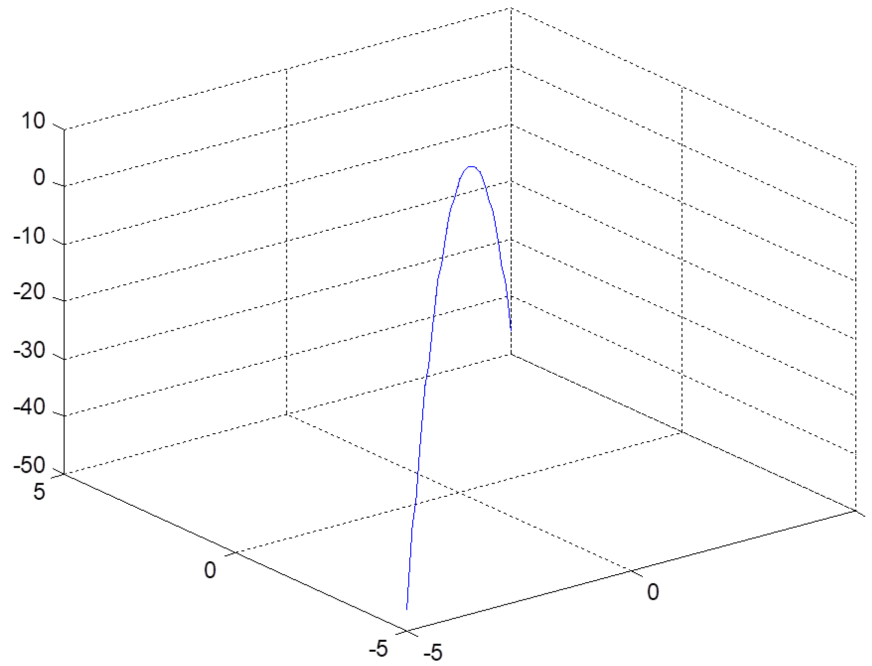
### 3-D Plot

plot3(x,y,z)    % Command

**Example #**. Plot the function

$$z = 4 - x^2 - y^2$$

```
>> x=linspace(-5,5,50);
>> y=x;
>> z=4-x.^2-y.^2;
>> plot3(x,y,z); grid on;
```




## Construction of Functions in the Command Window

**1. Inline function**

```
f1 =inline(expr)
f2=inline(expr, arg1, arg2,. . .  )
```

**Example**

```
>> f=inline('x^2+2*x*y')
f =
     Inline function:
     f(x,y) = x^2+2*x*y
>> v1=f(1, 2.2)
```

**Result**

```
v1 =
    5.4000
```

## Construction of Functions in the Command Window

### 2. Function_handle (@) )

handle=@(arglist) anonymous_function

To compute elementwise in array use

POWER with (.^) , DIVISION with (./)
and PTRODUCT with (.*)

**Example**

```
>> ff=@(x,y) x.^2+x./y
ff =
   @(x,y)x.^2+x./y

>> ff(1.1,2)
ans =
   1.7600
```

### 3. Function using Symbols

```
>> syms x y
>> ff(x,y)=x.^2+x./y

ff(x, y) =
             x^2 + x/y
```

```
>> ff(1.2, 2)          % returns result in fracttion
ans =
     51/25
>> ffval=eval(ff(1.2,2))
   % eval( ) is used to convert fraction to decimal form
ffval =
       2.04
```

**m-Files**

There are two types of programs (m-files) in MATLAB: Functions and Scripts.

**User Defined Functions**

To be created in function window.

To open: New → Function

To save: Save → enter file name and save

To run: Type function name in command window

To edit: Open → select the file from the list and edit. save again

```
function t=FF(a)
   t=7*cos(a)+2*a-1;
end
```

**m-Files**

The function which is created as an m-file and saved as FF.m.

To use the above function type in command window.

```
>> t=FF(2)
t =
   0.0870
```

**Scripts**

Scripts provide a set of MATLAB commands, comments, values, plotting commands, and so on.

A scripts that has been created and saved is executed by typing the file name at the MATLAB prompt in the command window or using save and run from the Debug menu.

To open: New → Script

To save: Save → enter file name and save

To run: Type script name in command window

To edit: Open → select the file from the list and edit. Save again

## Scripts

```
% Script TestProgm
%Values of f(x) for different values of x
x= x0;
disp('n   xn  f(xn)')
for i=1:nmax
    fx=f(x);
    n=i-1;
    disp([n,x,fx])
    x=x+h;
end
```

Save the script as TestProg.m

To execute the script from Command Window, type following commands:

```
>> clear
>> x0=1;
>> h=0.5;
>> f=inline('7.*cos(x)+2.*x-1')
f =
     Inline function:
     f(x) = 7*cos(x)+2*x-1
>> nmax=5
nmax =
     5
>> TestProg              % Type the Script name
```

## Output

```
        n          xn          f(xn)
        0     1.0000     4.7821
   1.0000     1.5000     2.4952
   2.0000     2.0000     0.0870
   3.0000     2.5000    -1.6080
   4.0000     3.0000    -1.9299
```

## Programming in MATLAB

Normally in a programming language, it is necessary to specify type of variable used in the program (integer, real, complex, and so on). MATLAB treats all variables as matrices (whatever dimension is needed) and perform the necessary calculations.

To repeat similar calculations several times for and while loops are used. Syntax are

***For Loops***

```
for   i = 1 :  k
      commands   . . .
end
```

***While Loops***

```
while  statement == true
      commands  . . .
end
```

**Example #**: Write  MATLAB codes for calculating n! using for loop.

```
>> clear
>> n=input('please input number = ');
fact=1;
i=1;
for i=1:n
   fact=fact*i;
   i=i+1;
end
disp(fact)
```

**Outcome:**

**please input number = 5**

**120**

Conditional execution can be indicated by ***if*** statement.

***if***   expression
    commands   . . .
***end***

If there are more alternatives, the form is

***if***  expression1
    commands   . . .
***elseif***  expression2
    commands   . . .
***elseif*** …
. . .
***end***

## ***Break*** and ***Error***

The ***break*** command causes MATLAB to jump outside the loop in which it occurs.
The ***error*** command abort function execution , displays a character string in the command Window, and returns control to the keyboard.

## Computer Algebra System (CAS) with MATLAB

MATLAB contributes to solve in numerous common mathematical areas such as calculus, linear algebra, algebraic equations differential equations and so on. MATLAB also provides symbolic calculations and manipulations symbolic mathematical expression. For this purpose we need to define the symbols and it can be done by using the MatLab default command ‘syms ’.

# Solve problems using Basic commands and Syntax

**Example #**: Solve the equation $x^2 - 5x + a = 0$, whether $a$ is a constant.

MATLAB codes are

```
>>syms x a
>> Solution=solve(x.^2-5.*x+a= = 0,x)      % solve(eqn, var) is to solve an equation
Solution=
 5/2 - (25 - 4*a)^(1/2)/2
 (25 - 4*a)^(1/2)/2 + 5/2
```

**Example #:** Find the general solution of differential equation

$$y'' + 3y' + 2y = e^{-x}.$$

```
>> clear
>> syms y(x)
>> Dy=diff(y);
>> D2y=diff(y,2);
>> GS=dsolve(D2y+3*Dy+2*y==exp(-x))     % dsolve(eqn)  solves D.E.
 GS =
x*exp(-x) - exp(-x) + C3*exp(-x) + C4*exp(-2*x)
```

# Representation of Numbers in MATLAB

**Rounding:**
The last retained digit is corrected up if the succeeding digit is greater than or equal to 5, otherwise chopped off.

2.30494 to 3 d.p. $\approx 2.305$
2.30494 to2 d.p. $\approx 2.30$

**Decimal places (d.p.)**:
The number of digits counted after the decimal marker.

**Significant figures (s.f.):**
All digits including zero are counted from the first non-zero digit.

0.0010345
$\approx 2s.f$ 0.0010
$\approx$ 3 s.f 0.00103
$\approx 4s.f.$ 0.001035

## Error Measurement

Numerical calculations can be in error due to the use of approximate values in the calculation. The following definitions are used in measuring the errors.

Absolute error $= \left|\text{True value} - \text{Approximate value}\right|$

Relative error$= \left|\dfrac{\text{True value} - \text{Approx. value}}{\text{True value}}\right| = \dfrac{\text{Absolute error}}{|\text{True value}|}$

$$\text{Percentage of error} = \text{Relative error} \times 100\ \%$$

**Note that** in absence of true value an approximate relative error, $\in_a$, can be estimated by using the relation

$$\in_a = \left| \frac{\text{Current approximation} - \text{Previous appoximation}}{\text{Current approximation}} \right| \times 100\ \%$$

**Rounding Error**

If 2.326 is a number rounded to 3 d.p., the true value α is

$$2.3255 \le \alpha < 2.3265 \text{ or } \alpha = 2.326 \pm 0.0005$$

Thus the maximum absolute error is $0.0005 = \frac{1}{2} \times 10^{-3}$

**If a number is rounded to *n* decimal places, the maximum absolute error is**

$$\tfrac{1}{2} \times 10^{-n}$$

Consider two numbers 235.3 and 0.003267 which are rounded to 4 s.f.. The errors can be estimated as follows

For 235.3, the relative error is $$\frac{\frac{1}{2}\times 10^{-1}}{2.353\times 10^{2}} = \frac{\frac{1}{2}\times 10^{-3}}{2.353} < \tfrac{1}{2}\times 10^{-3}$$

For 0.003267. the relative error is $$\frac{\frac{1}{2}\times 10^{-6}}{3.267\times 10^{-3}} = \frac{\frac{1}{2}\times 10^{-3}}{3.267} < \tfrac{1}{2}\times 10^{-3}$$

In general, **if a number is rounded to *n* significant figures the maximum relative error is** $\frac{1}{2}\times 10^{-n+1}$.

The table below shows various errors corresponding to the given true and approximate values.

| True value | Approximate value | Absolute error | Relative error | Percentage error |
|---|---|---|---|---|
| 3.141592 | 3.142 | 0.00041 | 0.00013 | 0.013 |
| 100000 | 99950 | 50 | 0.0005 | 0.05 |
| 0.00025 | 0.0003 | 0.00005 | 0.2 | 20 |

# Solve problems using Basic commands and Syntax

**Example #:** The solution of the quadratic equation $ax^2 + bx + c = 0$

is $x = (-b \pm \sqrt{b^2 - 4ac})/(2a)$

Write a MATLAB script to solve the quadratic equation with variable coefficients which gives variable significant digits.

## Solution:

```
% Script QuadEq for solution
clear all
 disp('Solution of Quadratic Equation')
% Equation : ax^2+bx+c=0
% Roots: x1= -b+sqrt(b^2-4ac)/(2a)
%        x2= -b-sqrt(b^2-4ac)/(2a)
abc=input('Supply a,b,c as [a,b,c]=');
a=abc(1); b=abc(2); c=abc(3);
x1=(-b+sqrt(b^2-4*a*c))/(2*a);
x2=(-b-sqrt(b^2-4*a*c))/(2*a);
Roots=[x1,x2]
disp('Roots to n significant digits')
n=input('Value of n = ');
Roots_n=vpa([x1; x2],n)
```

# Outcomes

- **Numerically solve problems by using different mathematical methods, built in function in MATLAB**
- **Visualization problems by data analysis**
- **Save time for solve problems**

# Try to do yourself

**Exercise 1:** Write script and solve the following equation then correct it to ten significant figures.

$$6x^2 - 9886x + 1 = 0$$

**Exercise 2:** Find the general solution of the following ordinary differential equation (ODE)

$$y'' - 2y' + 10y = 5x - e^{3x}$$

**Exercise 3:** Calculate the Celsius temperature by using the following relation between $F$ and $C$

$$\frac{F-32}{180}=\frac{C}{100}$$

where the range of Fahrenheit temperatures from 10 to 200 with interval 5. Then print these values with the proper headings by using the "fprintf" command in MATLAB.

# References


## Text Book:

Applied Numerical Methods with MATLAB for Engineers and Scientists- S.C. Chapra, 4th Edition, 2017, McGraw Hill-Europe.

## Reference Book:

Numerical Methods in Engineering with MATLAB – Jaan Kiusalaas, $4^{th}$ Edition, 2018, CAMBRIDGE UNIVERSITY PRESS, UK.

Applied Numerical Methods With Matlab for Engineers and Scientists ( Steven C.Chapra).