Textbook :-

Getting started with Matlab, updated version 7.8, Rudra Pratap, Oxford University Press, 2010.

Chapter - 1

Introduction

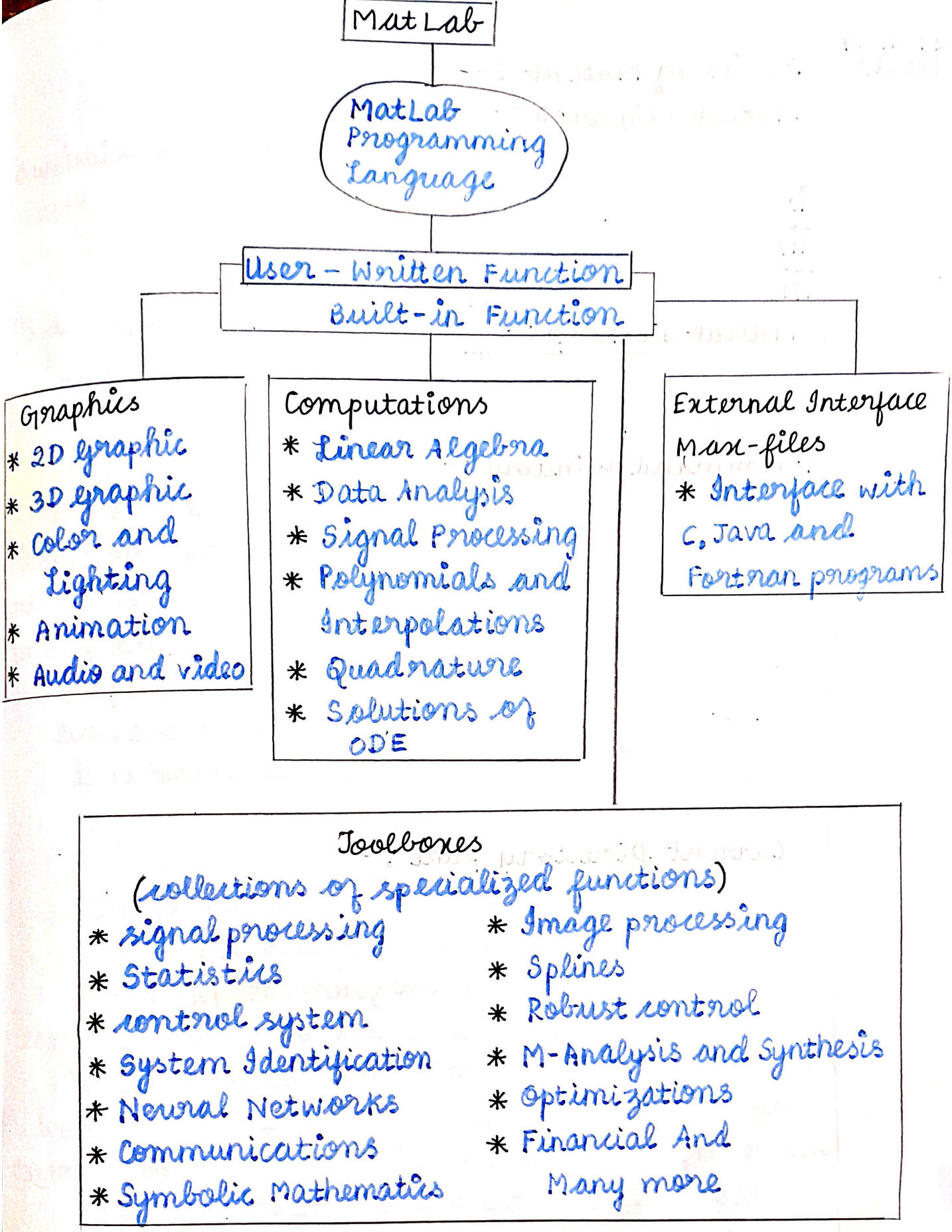
Matlab :-

Matlab is a software package for high performance numerical computations and visualization. It gives an interactive environment with hundreds of built-in functions for technical computations, graphics, animation. The name MATLAB stands for MATrix LABoratory

MatLab tools (Applications of MatLab) :-

MatLab built-in function provide excellent tools for linear algebra computation, data analysis, signal processing, optimisation, numerical solution of ODE and many other types of scientific computation.

Many functions for 2D and 3D graphics and animations are available in MatLab. The tools are collection of functions written for special applications such as symbolic computations special applications such as image processing, statistics, control system design, neural networks. There are more than 50 tool boxes are available in MATLAB.



Schematic diagram of MATLAB Main features

Basics of MatLab :-

MatLab Windows :-

MATLAB works through three basic windows

i) ~~Command Window~~ MATLAB Desktop
ii) Figure Window
iii) Editor Window

Matlab Desktop :-

This is where MATLAB puts you when you launch it.

MATLAB Desktop consists of the following [Sub-Windows] 10M|5)

1. Command Window :-

This is the main window and it has the MATLAB command prompt (>>). All the commands, including the user-written programs for running are typed in this window at the MATLAB prompt. This window contains ~~a~~ other smaller windows (or) panes. As software packages become more and more powerful, the creators add more and more features.

Current Directory pane :-

The pane is located on the left of the command window in the default MATLAB desktop layout. In this all your files from the current directory are listed and we can access the MATLAB files when required, the selected directory is also reflected in the little window above the command window marked ~~the~~ current directory. The little window and current directory are interlinked.

(File) Details pane :-

It is located just below the current directory. The pane shows the details of files you select in the current directory pane. These details are normally limited to listing of

variables from MAT-file (A binary data file), showing the details of titles of M-file and listing heading of cells if present in the M-file

2M(S) Work Space pane :-

The sub-window list all variable that you have generated so far and shows their type and size] 2M(S)

Command History pane :-

All the commands typed on the MATLAB prompt in the command window get recorded (For example you worked on Monday then on Tuesday, Wednesday etc.). You can select a command from this window and execute it in the command window by double-clicking on it. You can also select a set of commands from this window and create an M-file.

(2) 2. Figure Window :-

The output of all graphics command typed in the command window are flushed to the graphic(or) figure window. The user can create as many figure windows as a system memory will allow.

(3) 3. Editor Window :-

In this window you can write, edit, create and save your own programs in the file called M-file. You can use any text editor to carry out this tasks. On most system, MATLAB provides its own built-in editor. After editing is completed, the control is returned to MATLAB.

Online help :-

i) Online documentation :-

MATLAB provides online help for all its built-in functions and program language. The commands look for, help, helpwin and helpdesk 2M(S)

provide online help.

ii) Demo :-

MATLAB has demonstration programs that shows many of its features. The program includes tutorials. Type demo at the MATLAB prompt that brings demonstration program and follow the instructions on the screen.

Input - Output

MATLAB taking input from the screen and flushing (giving) the output on the screen. The input and outputs are received and shown in the files.

i) Data types :-

The fundamental data type in MATLAB is array. It also have distinct data object namely integer, doubles (real numbers), matrices, character string, structures and cells.

For example, there is no need to declare variables as real or complex numbers. When a real number is entered as a value of a variable, MATLAB automatically sets the variable real (double)

ii) Dimensioning :- 2M(S)

Dimensioning is automatic in MATLAB. No dimension statements are required for vector or arrays. You can find the dimensions of an existing matrix or a vector with the size and length commands 2M(S)

iii) Case sensitivity :-

MATLAB is case sensitive, it differentiate

a and A are different variables. Most of the MATLAB programs are typed in lower case letters. You can turn case sensitive on and off with casesen command.] 5M15)

iv) Output display :-

The output of every command is displayed on the screen. A semicolon at the end of the command suppresses the screen output, except for graphics and online help command. The following facilities are provided for controlling the screen output.

a) Paged output :-

To direct MATLAB to show one screen of output at a time if we type more at the MATLAB prompt, it will display all the output once on the screen

b) Output format :-

The computations inside MATLAB are performed using double precision. The appearance of floating point numbers on the screen is controlled by the output format. The printed value of 10 π in different formats are

format short 31.4159
format short e 3.1416e+001
format long 31.415926535897 93...
etc...

Additional format compact and format loose, control the spacing above and below the displayed lines.

Command History :-

MATLAB saves previous typed commands in a buffer. These commands can be recalled with the up arrow (↑). This helps in editing previous

commands. Also we can get previous command by double-click on a command in the command pane.

Types of files :-

MATLAB can read and write several types of files. There are mainly five different types of files used for storing data or programs.

(i) M-file :-

M-files are standard ASCII text files with a .m extension to the file name. There are two types of files

a) Script file
b) function file

Most of the MATLAB programs are saved in M-file.

(ii) Mat-file :-

Mat-files are binary data files with a .mat extension to the file name. The mat-files are created by MATLAB and save the data with save command. The data is written in special format that only MATLAB can read. Mat-files can be loaded in to MATLAB with load command.

(iii) Fig-files :-

Fig-files are binary figure-files with a .fig extension that can be opened in MATLAB figures. Such a files are created by saving a figure in the format using save or save As options from the file menu. A fig-file contains all the information required to create the figures. This type of files can be opened with the open filename.fig command

iv) P-file :-

P-files are compiled M-files with a .p extension that can be executed in MATLAB directly. These files are created with the P-code command

v) Mex-files :-

Mex-files are MATLAB callable Fortran, C and Java programs with a .mex extension filename. (10M/S)

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chapter-2

Tutorials Lessons

2.1 **Lesson 1 : A minimum MATLAB session**

i) The arithmetic operations are

+ Addition
- Subtraction
* Multiplication
/ Division
^ Exponentiation

ii) The commands sin, cos, log, format, quit etc.... are also used

Exercise

1. **Arithmetic operations**

Compute the following quantities

5M/S) (i) $\frac{2^5}{2^5-1}$ and compute with $\left(1-\frac{1}{2^5}\right)^{-1}$

5M/S) (ii) $3\frac{\sqrt{5}-1}{(\sqrt{5}+1)^2}-1$. The square root $\sqrt{x}$ can be calculated with the command sqrt(x) / x^0.5

5M/S) (iii) Area $= \pi r^2$ with $r = \pi^{1/3} - 1$ (π is pi in MATLAB)

MATLAB command	Result
i) 2^5/(2^5-1)	1.0323
(1-1/2^5)^-1	1.0323

ii) (3*(sqrt(5)-1))/((sqrt(5)+1)^2)-1	-0.6459
iii) Area = pi*(pi^(1/3)-1)^2	0.6781

Exponential and logarithms

Calculate the following quantities

Expression	MATLAB command	Result
e^3	exp(3)	20.0855
$\ln(e^3)$	log(exp(3))	3
$\log_{10}(e^3)$	log10(exp(3))	1.3029
$\log_{10}(10^5)$	log10(10^5)	5
$e^{\pi\sqrt{163}}$	exp(pi*sqrt(163))	2.6254e+17

Solve $3^x = 17$ for x and check for result

Solution:-

$$3^x = 17$$

Taking ln on both sides

$$x \ln 3 = \ln 17$$

$$x = \frac{\ln 17}{\ln 3}$$

MATLAB command

x = log(17)/log(3)

Result:- 2.5789

Trigonometry

Expression	MATLAB Command	Result
sin(π/6)	sin(pi/6)	0.5000
cosπ	cos(pi)	-1.0000
tan(π/2)	tan(pi/2)	1.6331e+16
$\sin^2\pi/6 + \cos^2\pi/6$	(sin(pi/6))^2+(cos(pi/6))^2	1.0000
$y = \cosh^2 x - \sinh^2 x$ with $x = 32\pi$	x = 32*pi y = (cosh(x))^2-(sinh(x))^2	0

Complex Numbers

	Expression	MATLAB command	Result
i)	$\frac{1+3i}{1-3i}$	(1+3i)/(1-3i)	-0.8000+0.6000i
ii)	$e^{i\pi/4}$	exp(i*(pi/4))	0.7071+0.7071i

iii) Execute the command exp(pi/2*i) and exp(pi/2i). Can you explain the difference between the results.

$\exp(pi/2*i) = e^{\pi/2 i} = \cos\pi/2 + i\sin\pi/2 = 0.0000+1.0000i$

$\exp(pi/2i) = e^{\frac{\pi}{2i}} = e^{-\frac{\pi}{2}i} = \cos\pi/2 - i\sin\pi/2 = 0.0000-1.0000i$

By checking Euler's formula to the above problem when i in the product we get the result the imaginary part of the result is multiplied by i. When i in the denominator we can get the conjugate of the above result.

2.2 **Lesson 2: Creating and working with array of numbers**

In this section we learn how to create an array and how to perform arithmetic and trigonometric operations on them.

[Array :-

An array is a list of numbers or expressions arranged in horizontal rows and vertical columns.]

[When a array has only one row or column is called a vector. An array with m-rows and n-columns is called matrix of size m×n.]

Array operations :-	Meaning
• *	term-by-term multiplication
• /	term-by-term division
• ^	term-by-term exponentiation.

Note

i) 1-D (one dimension) array is a vector

ii) 2-D (two dimension) array is a matrix

09-12-19 (Mon)

Lesson 2.2

Example

```
>> x = [1 2 3]  (or) x = [1,2,3]'   // x is a row vector with 3 elements
   x = 1 2 3
>> y = [2; 1; 5]                    // y is a column vector with 3 elements
   y = 2
       1
       5
>> z = [2 1 0];                     // value does not display on the screen.
>> a = x+z
   a = 3 3 3                        // adding two vectors of same size
>> b = x+y                          // x and y are two different size
>> a = x.*z                           of the matrix, error: matrix
   a = 2 2 0                          dimension must agree.
>> b = 2*a                          // New value of a = 2 2 0 old value
   b = 4 4 0                          is repeated
>> x = linspace(0, 10, 5)           // create a vector x with five
   x = 0  2.5000  5.0000  7.5000  10.000   elements linearly spaced
                                           between 0 and 10
>> y = sin(x);   y = 0  0.5985  -0.9589  0.9380  -0.5440
>> z = sqrt(x).*y
   z = 0  0.9463  -2.1442  2.5688  -1.7203
```

(initial value; final value; creates 5 elements linearly spaced)

Exercise :-

1. The equation of a straight line $y = mx + c$ where m and c are constants. Compute the y-co-ordinates of the line with slope $m = 0.5$ and intercept $c = -1$ at the following co-ordinates

   $x = 0, 1.5, 3, 4, 5, 7, 9$ and 10

```
>> x = [0 1.5 3 4 5 7 9 10];
>> y = 0.5*x - 2
   y = -2.0000 -1.2500 0 0.5000 1.5000 2.5000 3.0000
```

2. Multiply, divide and exponentiation vectors

5M(S) + 5M(S)

[Create a vector t with 10 elements 1, 2, 3, ... 10. Now compute the following

i) $x = t \sin t$

ii) $y = \frac{t-1}{t+1}$

iii) $z = \frac{\sin(t^2)}{t^2}$

Solution:-

```
>> t = 1:10;
>> x = t.*sin(t)
>> y = (t-1)./(t+1)
>> z = sin(t.^2)./(t.^2)
```

] 5M(S) + 5M(S)

3. Points on a circle:-

All points with co-ordinates $x = r\cos\theta$ and $y = r\sin\theta$ where r is a constant lies on a circle with radius r that is they satisfies the equation $x^2 + y^2 = r^2$. Create a column vector for θ with $0, \pi/4, \pi/2, 3\pi/4, \pi$ and $5\pi/4$ take $r = 2$ and compute a column vector x^2y. now check that x and y satisfy equation of circle by computing the radius $r = \sqrt{x^2 + y^2}$

Solution:-

```
Theta = [0; pi/4; pi/2; 3*pi/4; 5*pi/4]
r = 2;
x = r*cos(theta);
y = r*sin(theta);
z = x.^2 + y.^2
```

x = 2.0000, 1.4142, 0, -1.4142, -1.4142

y = 0, 1.4142, 2, 1.4142, 1.4142

geometrically series

Sum the geometric series $1+x+x^2+\ldots+x^n$ approaches the limit $\frac{1}{1-x}$ for $x<1$ as $n\to\infty$

Create a vector n of 11 elements from 0 to 10

Take $x = 0.5$ and create another vector.

$x = [x^0, x^1, x^2, \ldots x^n]$ with $x = x.\hat{}\, n$. Now take the sum of the vector with the command

$S = sum(x)$ (S is a sum of the actual series)

Calculate the limit $\frac{1}{1-x}$ and compute the sums.

Repeat the procedure taking n from 0 to 50.

Solution :-

```
n = 0:10;
x = 0.5;
x = x.^n;
S1 = sum(x)
```

$1+x+x^2+\ldots+x^{10}$ $S_1 = 1.9990$

```
x = 0:50;
x = 0.5;
x = x.^n;
S2 = sum(x)
```

$1+x+x^2+\ldots+x^{50}$ $S_2 = 2.0000$

```
x = 0:100
x = x.^n
S3 = sum(x)
```

$1+x+x^2+\ldots+x^{100}$ $S_3 = 2$

[Creating and printing simple plots]

MATLAB command :- (for plotting 2D or 3D graphs)

i) plot :

It creates a 2D line plot.

ii) Axis :

changes the aspect ratio of the x-axis and the y-axis.

iii) x-label :- annotates the x-axis

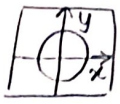
iv) y-label :- annotates the y-axis

v) Title :- puts a title on the plot

vi) print :- prints a hard copy

Plotting a circle :-

Plot a unit circle with $x = \cos\theta$ $y = \sin\theta$ $0 \le \theta \le 2\pi$

output:  circle of unit radius

MATLAB program :-

```
theta = linspace(0,2*pi,100); // creates a linearly spaced
x = cos(theta);                    100 elements
y = sin(theta);    // calculate x and y co-ordinate
plot(x,y)
axis('equal');     // plot x vs y
x label('x')       // set the length scale of two axis is same
y label('y')
title('circle of unit radius') // put the title on plot
print  // print on the default printer
```

5M(S) 2M(S)

Exercise 2.3 :- A simple sine plot

Plot $y = \sin x$, $0 \le x \le 2\pi$, taking 100 linearly spaced points in the given intervals, label the axes and put "plot created by your name" in the title

Solution :-

```
x = linspace(0, 2*pi;100);
y = sin(x);  } (or) plot (x, sin(x))
plot(x,y)
x label('x');
y label('y');
title('plot created by ARRUNA')
```

5M(S)

---

3. 5M(S)

An exponentially decaying sine plot :-

Plot $y = e^{-0.4x} \sin x$ $0 \le x \le 4\pi$ taking 10, 50 and 100 points in the interval.

Solution :-

```
x = linspace(0, 4*pi, 10); // x with 10 points
y = exp(-0.4 * x).* sin(x);
plot(x,y)
```

```
x = linspace(0*4*pi*50); // with 50 points
y = exp(-0.4*x).*sin(x);
plot(x,y)
x = linspace(0,4*pi,100); // with 100 points
y = exp(-0.4*x).*sin(x)
plot(x,y)]
```

Space curve :-

Use the command plot 3(x,y,z) to plot the circular helix

$x(t) = \sin t, y(t) = \cos t, z(t) = t, \quad 0 \le t \le 20$

Solution :-

```
t = linspace(0,20,100);
plot 3(sin(t),cos(t),t)
```

Overlay plot :-

plot $y = \cos x$ and $z = 1 - \frac{x^2}{2} + \frac{x^4}{24}$ for $0 \le x \le \pi$ on the same plot.

Solution :-

```
x = linspace(0,pi,100);
y = cos(x);
z = 1-x.^2/2 + x.^4/24;

plot(x,y,x,z)
plot(x,y,x,z,'--')
legend('cos(x)','z')
```

Log scale plots :-

The plot commands semilog x, semilog y and loglog plot, the x values, y values and both x and y values on a $\log_{10}$ scale respectively. Create a vector $x = 2:10:1000$ plot x vs x^3 using the three log-scale plot commands.

Solution :-

```
x = 0:10:1000
y = x.^3
semilogx(x,y)
semilogy(x,y)
loglog(x,y)
```

2.4 (2014 SM(S))

Creating, saving and executing a script file :-

Script file :-

A script file is a user created file with a sequence of MATLAB commands in it. The script file must be saved with a .m extension to its name, it is also called a M-file

A script file is executed by typing its name at the command prompt. (without the .m extension)

Note :-

A line starting with '%' sign are ignored by MATLAB as a command.

1. ✓ Program to draw a unit circle :-

```
% CIRCLE : The program is in script file
% The program is written by Anruna on 13.12.2019.
%---------
theta = linspace(0,2*pi,100); % create a vector theta
x = cos(theta);               % create x co-ordinates
y = sin(theta);               % create y-co-ordinates
plot(x,y)                     % plotting the graph
axis('equal');                % set equal scale on axis
title('circle of unit radius') % put the title.
```

2. ✓ Show the center point with a "+" of a unit circle :

```
% show the unit circle with + sign at the centre
% the program written during the third hour
```

Solution :-

```
x = 0:10:1000
y = x.^3
semilogx(x,y)
semilogy(x,y)
loglog(x,y)
```

2.4 (5M)(S) 2.4 Creating, saving and executing a script file :-

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---

1. Program to draw a unit circle :-

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plot(x,y)                     % plotting the graph
axis('equal');                % set equal scale on axis
title('circle of unit radius') % put the title.
```

---

2. Show the center point with a "+" of a unit circle :

✓

```
% show the unit circle with + sign at the centre
```

A function file is also like a script file. except it has a function definition on the top that defined the input and output arg

1. Write a program to compute the factorial n. ie) n!

function fact n = factorial(n);
% FACTORIAL: program to compute n! using func
% call the syntax
%----
fact n = 1; % initialize, also 0! = 1
for k = n:-1:1 % go from n to 1
fact n = fact ~~k~~ n * k; % multiply n by n-1, n-2, etc
end.

2.6 Working with arrays and Matrices

Array :- 2D array is a

A list of numbers (elements) arranged in rows and column ~~are called an arrays~~.

An array with m-rows and n-columns is called an m×n arrays and it has a total of m·n entries

The rows and columns of a matrix ~~are~~ identified as with A(i,j) are called indices.

The arrays operation are carried out element by element operations.

```
>> A = [1,2,3; 4,5,6; 7,8,8]
A =  1  2  3
     4  5  6      Aij
     7  8  8
```

Matrices are entered row wise. Rows are separated by semicolon and columns are separated by space or commas.

```
>> A(2,3)
ans    [Element: A
```

4. Enter the matrices in MATLAB or Enter the following 3 matrices

$A = \begin{pmatrix} 2 & 6 \\ 3 & 9 \end{pmatrix}$ $B = \begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix}$ $C = \begin{pmatrix} -5 & 5 \\ 3 & 3 \end{pmatrix}$

Solution :-

```
A = [2,6; 3,9]
B = [1,2; 3,4]
C = [-5,5; 3,3]
```

2.07 Lesson 7 :- Working with Anonymous functions.

[Anonymous function :-

Anonymous function is a function of one or more variables that you can create on the command line for subsequent evaluation. Such a function are useful to evaluate the function several times with different input during a single MATLAB session.

For example

$f(x) = x^3 - 32x^2 + (x-22)x + 100$

we can evaluate the above equation by giving different values of x.

[The syntax of anonymous function is

fn_name = @(list of input variable) function expression

Here fn_name is the name of the function or handle of the function. The symbol @ assigns the values to the defined functions. The syntax @(list of input variable) tells the MATLAB that you are defining an anonymous function.]

Problem :-

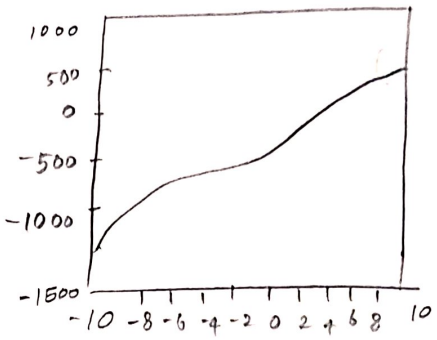
1. Create anonymous function

$f(x) = x^3 - 3x^2 + x\log(x-1) + 100$ and find $f(0)$, $f(1)$, $f(2)$ and $f(10)$

Solution :-

```
>> f = @(x) x^3 -3*x^2 +x*log(x-1) +100
 f = @ x^3 -3*x^2 +x* log(x-1) +100
>> f(0)
  ans =
     100
>> f(1)
  ans =
    -Inf
>> f(2)
  ans =
    96.0000
>> values = [f(0) f(1) f(2) f(10)]
 values =
   100.0000   -Inf    96.0000   821.9722
>> f = @(x) x.^3 - 3*x.^2 + x.*log(x-1) +100
>> values = [f(0) f(1) f(2) f(10)]
 values =
 100.000   -Inf   96.0000   821.9722
```

```
x = linspace(-10, 10);
plot(x, f(x))
```



2. Create three anonymous functions corresponding to the three expressions

$f(x) = x^4 - 8x^3 + 17x^2 - 4x - 20$

$g(x) = x^2 - 4x + 4$

$h(x) = x^2 - 4x - 5$

a) Evaluate $f(x) - g(x)h(x)$ at $x = 3$

b) Evaluate $f(x) - g(x)h(x)$ at $x = [1\ 2\ 3\ 4\ 5]$

c) Evaluate $\frac{f(x)}{g(x)} - h(x)$ for any x

Solution :-

```
>> f = @(x) x^4 -8*x^3 +17*x^2 -20 -4*x
   g = @(x) x^2 -4*x +4
```

```
h = @(x) x^2 - 4*x - 5
```

a)
```
f = f(3) - g(3) * h(3)
f =
     6
```
// l = f(x) - g(x) * h(x)
l(3) =
6

b)
```
K = @(x) f(x) - g(x) * h(x)
values = [K(1) K(2) K(3) K(4) K(5)]
values =
    -6    -8    -6     0    10
```

c)
```
l = @(x) (f(x)/g(x)) - h(x)
values = [l(1) l(2) l(3) l(4) l(5)]
values =
   -6.0000      -Inf   -6.0000         0    1.1111
```

3. Create the function $f(x) = x^2 - \sin(x) + \frac{1}{x}$
a) Find f(0), f(1) and f(π/2)
b) Vectorise f and evaluate f(x) where x = [0 1 π/2 π]
c) create x = linspace (-1,1), evaluate f(x) and plot x Vs f(x)

Solution :-
```
>> f = @(x) x^2 - sin(x) + 1/x
f = @(x) x^2 - sin(x) + 1/x
```
a)
```
>> [f(0) f(1) f(pi/2)] = values
values =
      Inf    1.1585    2.1040
```
b)
```
>> values1 = [f(0) f(1) f(pi/2) f(pi)]
values1 =
      Inf
    1.1585
    2.1040
   10.1879
```
c)
```
>> x = [0 1 pi/2 pi]
>> f = @(x) x^2 - sin(x) + 1/x
```

```
>> x = linspace (-1, 1);
>> plot (x, f(x));
```

4. Using anonymous function compute the compound interest on an investment given

$$x = x_0 \left(1 + \frac{r}{100}\right)^n$$

where x = accumulated amount,

x_0 = initial investment

r = rate of annual interest in %

and n = number of years.

Using this function compare the growth rate of $ 1000 investment over a period of 8 years earning an interest rate of 9% with that over a period of 9 years earning an interest rate of 8%.