Matlab Examples

(v. 2012.1, Fall 2012, prepared for MAE502/MSE502 by HP Huang)

These examples illustrate the usages of the basic Matlab commands. More detailed documentations of the commands are available at mathworks.com (the maker of Matlab).

Part 1. Write your first Matlab programs

Ex. 1 Write your first Matlab program

```
a = 3;
b = 5;
c = a+b
```

Output:

8

Remarks: (1) The semicolon at the end of a statement acts to suppress output (to keep the program running in a "quiet mode"). (2) The third statement, *c = a+b*, is not followed by a semicolon so the content of the variable *c* is "dumped" as the output.

Ex. 2 The meaning of "a = b"

In Matlab and in any programming language, the statement "a = b" does not mean "a equals b". Instead, it prompts the action of *replacing the content of a by the content of b*.

```
a = 3;
b = a;
b
```

Output:

3

Remark: Think of the two "variables" **a** and **b** as two buckets labeled "a" and "b". The first statement puts the number 3 into bucket **a**. The second statement puts **the content of bucket a** into bucket **b**, such that we now have "3" in bucket **b**. (The content of bucket **a** remains unchanged after this action.) The third statement dumps the content of bucket **b** so the final output is "3".

Ex. 3 Basic math operations

```
a = 3;
b = 9;
c = 2*a+b^2-a*b+b/a-10
```

Output:

53

Remark: The right hand side of the third statement includes all 4 of the basic arithmetic operators, + (addition), - (subtraction), * (multiplication), and / (division), in their usual meaning. It also includes the symbol, ^, which means "to the power of", so "b^2" means (the content of b) to the power of 2, i.e., $9^2 = 81$. The right hand side of that statement is first evaluated: r.h.s. = $2 \times 3 + 9^2 - 3 \times 9 + 9/3 - 10 = 53$. The content of r.h.s., now 53, is then assigned to the variable c in the left hand side. Since this statement is not followed by a semicolon, the content of c is dumped as the final output.

Ex. 4 The meaning of "a = b", continued

```
a = 3;
a = a+1;
a
```

Output:

4

Remark: The value of variable **a** is 3 after the first statement. In the second statement, the right hand side is first evaluated to be 3+1 = 4. This value is then used to replace the old content of **a**, so **a** becomes 4 instead of 3.

Ex. 5 Formatted output

```
fprintf('Hello')
```

Output:

Hello

Ex. 6 Formatted output

```
a = 3;
b = a*a;
c = a*a*a;
d = sqrt(a);
fprintf('%4u square equals %4u \r', a, b)
fprintf('%4u cube equals %4u \r', a, c)
fprintf('The square root of %2u is %6.4f \r', a, d)
```

Output:

```
   3 square equals    9
   3 cube equals    27
 The square root of  3 is 1.7321
```

Remarks: The command "fprintf" is for formatted output, using the format specified in the first string '...' in the parentheses. The "%4u" (4-digit integer) and "%6.4f" (real number that preserves 4 digits to the right of the floating point) are the format for the variable(s) for output. The "sqrt" in the 4th statement is the intrinsic function for square root.

Ex. 7 Arrays

```
a = [3  6  7];
b = [1  9  4];
c = a + b
```

Output:

```
4  15  11
```

Remarks: (1) Both *a* and *b* are given as a three-element array. In the third line, the operation of "*a*+*b*" results in element-by-element addition

Ex. 8 Extracting an individual element of an array

```
a = [3  6  7];
b = [1  9  4  5];
c = a(2) + b(4)
```

Output:

c = 11

Remark: If **b** is a one-dimensional array, **b**(*n*) is the *n*-th element of that array. Since a(2) is 6 and b(4) is 5, the 3rd statement leads to c = 6+5 = 11.

Ex. 9 Comment

```
%
% This program demonstrates how to "comment out"
% a segment of code
%
A = 3;
B = A*A;
%
% B = 2*B   <--- This statement is not executed
%
C = A+B
```

Output:

c = 12

Ex. 10 Continuation to next line

```
summation1 = 1 + 3 + 5 + 7 ...
 + 9 + 11
```

Note: The three periods (...) allow continuation to the next line of commands. The two lines in the above example are essentially one line of "summation1 = 1+3+5+7+9+11".

Ex. 11 "Clear" a variable

```
c1 = 3;
c2 = c1+5;
clear c1
c1
```

Output:

??? Undefined function or variable 'c1'.

Remarks: We see an error message because the variable "c1" no longer exists. It is purged from the computer memory by the "clear" command. Note that the command does not just act to delete the content of a variable, but it kills the variable outright. The 3rd statement can be useful if c1 is a big array that occupies a lot of memory but is no longer needed for the rest of the program. The 3rd statement only kills c1, while c2 (= 8) still exists. A "clear" command not followed by any variable will kill all variables.

Ex. 11 Intrinsic math functions and constants

```
x = pi;
y = sin(pi/2)
z = exp(-sin(pi/2))
```

Output:

y = 1
z = 0.3679

Remarks: "pi" (= 3.14159...) is a reserved intrinsic constant. A function within a function is allowed. The innermost function will be evaluated first, so the 3rd statement leads to z = exp(-1) = 0.3679.

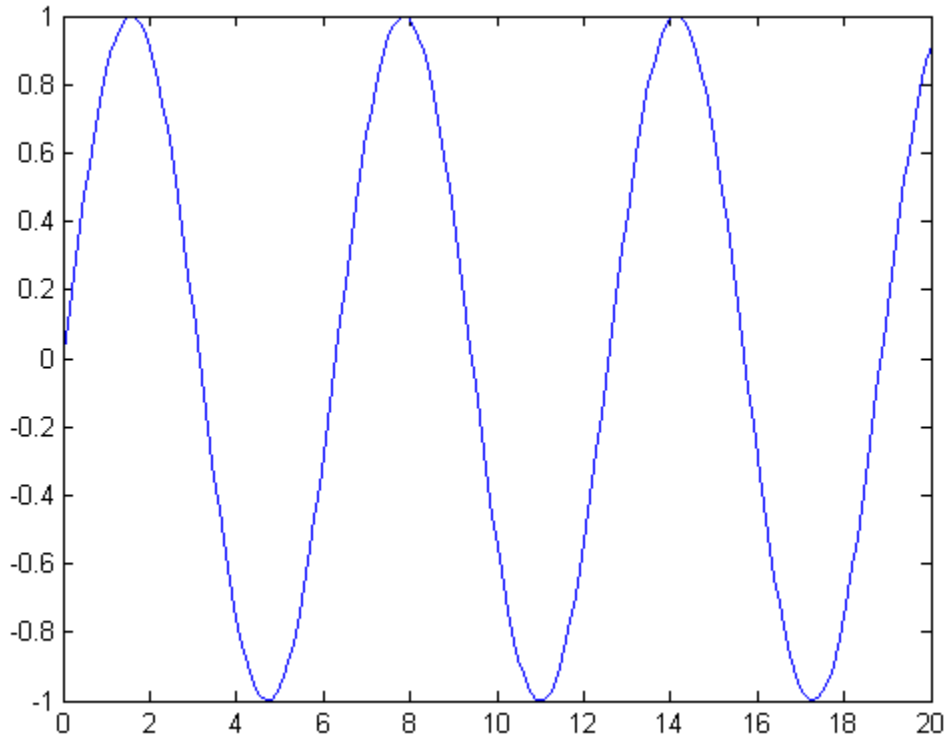
Ex. 12 Naming a variable

(i) Matlab variables are case sensitive. For example, "ASU" and "asu" are two different variables. (ii) An underscore (_) or a number (0-9) can also be part of the name of a variable. For example, "MAE_384" is a legitimate variable name. (iii) Some names are reserved for special constants. For example (see Ex. 11), "pi" is an intrinsic constant with a fixed value of 3.14159...

Ex. 13 Making a quick plot

```
x = [0:0.1:20];
y = sin(x);
plot(x,y)
```

The outcome will be the following plot:



Remarks: This only serves as a very quick example of what Matlab can do in making plots. will have more detailed discussions on the use of arrays and Matlab's graphic tools in later lectures. The first line is equivalent to x = [0 0.1 0.2 0.3 ... 19.8 19.9 20]. It assigns the content of x which is an array of 201 elements. The "0:0.1:20" means the 201 numbers are evenly spaced. They start from 0 and end at 20 with an increment of 0.1. The second line gives the content of the new array, y, as

y = [sin(x(1)) sin(x(2)) sin(x(3)) ... sin(x(200)) sin(x(201))] ,

or

y = [sin(0) sin(0.1) sin(0.2) ... sin(19.9) sin(20)] .

The 3rd line makes a plot of y vs. x.

Part 2. Basic looping

1. The *for* loop

Ex. 14 Loop: Using **for** command

```
b = 3;
for k = 1:5
 b
end
```

Output:

```
3
3
3
3
3
```

Remark: The blue-colored segment in lines 2-4 forms a "for-loop". The statement sandwiched between "for k = 1:5" and "end" is repeated 5 times, with the "k" index going from 1 to 5 step 1.

Ex. 15 *For* loop: Utility of the dummy index

```
b = 3;
for k = 1:5
 b^k
end
```

Output:

```
3
9
27
81
243
```

Remark: The outputs are 3^1, 3^2, 3^3, 3^4, and 3^5. the value of "k" keeps changing as we go through the loop

Ex. 16 *For* loop: More on the dummy index

```
sum1 = 0;
for k = 1:9
  sum1 = sum1+k;
end
sum1
```

Output:

45

Remark: this program performs the summation of 1+2+3+4+5+6+7+8+9 (= 45).

Ex. 17 *For* loop: More on the dummy index

```
sum1 = 0;
for k = 1:2:9
  sum1 = sum1+k;
end
sum1
```

Output:

25

Remark: this program performs the summation of 1+3+5+7+9 (= 25). The command "for k = 1:2:9" means we go through the loop only 5 times. First time with k = 1, second time with k = 1+2 (=3), third time with k = 1+2+2 (=5), and so on. The looping stops once k reaches 9.

Ex. 18 Treatment of array within a loop

```
b = [3  8  9  4  7  5];
sum1 = 0;
for k = 1:4
  sum1 = sum1+b(k);
end
sum1
```

Output:

24

Remark: This program performs the summation of sum1 = b(1)+b(2)+b(3)+b(4) = 3+8+9+4 = 24

Ex. 19 Treatment of array within a loop

```
b = [3  8  9  4  7  5];
sum1 = 0;
for k = 1:2:5
  sum1 = sum1+b(k);
end
sum1
```

Output:

19

Remark: This program performs the summation of sum1 = b(1)+b(3)+b(5) = 3+9+7 = 19

Ex. 20 Double loop

```
sum1 = 0;
for n = 1:2
  for m = 1:3
    sum1 = sum1+n*m;
  end
end
sum1
```

Output:

16

Remark: this program performs the summation of
Sum1 = 1*1+1*2+1*3 +2*1+2*2+2*3 = 16

Ex. 21 Double loop

```
for n = 1:2
  for m = 1:3
    fprintf('n = %3u  m = %3u \r', n, m)
  end
end
```

Output:

n = 1 m = 1
n = 1 m = 2
n = 1 m = 3
n = 2 m = 1
n = 2 m = 2
n = 2 m = 3

Ex. 22 More complicated use of loop and index

```
b = [2  5  7  4  9  8  3];
c = [2  3  5  7];
sum1 = 0;
for k = 1:4
   sum1 = sum1+b(c(k));
end
sum1
```

Output:

24

Remark: This program performs the summation of
sum1 = b(c(1))+b(c(2))+b(c(3))+b(c(4))
= b(2)+b(3)+b(5)+b(7)
= 5+7+9+3
= 24

Part 3. Basic branching

Ex. 23 The *if* command

```
num1 = 7;
if (num1 > 5)
   fprintf('%4u is greater than 5 \r', num1)
else
   fprintf('%4u is less than or equal to 5 \r', num1)
end
```

Output:

7 is greater than 5

Same program, but change first line to "num1 = 3;"

Output:

3 is less than or equal to 5

Remark: In this program, if (num1 > 5) (num1 is greater than 5) is true, the statement "fprintf('%4u is greater than 5 \r', num1)" is executed. Otherwise, the statement "fprintf('%4u is less than or equal to 5 \r', num1)" is executed.

Ex 24 *if - elseif - else* (This example is self-explanatory. Try to change the given value of num1 and observe the outcome.)

```
num1 = 4;
if (num1 >= 5)
   fprintf('%4u is greater than or equal to 5 \r', num1)
elseif (num1 > 1)
   fprintf('%4u is less than 5 but greater than 1 \r', num1)
elseif (num1 == 1)
   fprintf('%4u equals 1 \r', num1)
elseif (num1 > -3)
   fprintf('%4u is less than 1 but greater than -3 \r', num1)
else
   fprintf('%4u is less than or equal to -3 \r', num1)
end
```

Ex 25 An application - determine whether a given year is a leap year (try to change the given value of nyear and observe the outcome)

```
nyear = 1975;
if (mod(nyear, 400) == 0)
   fprintf('%6u is a leap year', nyear)
elseif (mod(nyear,4) == 0) & (mod(nyear,100) ~= 0)
   fprintf('%6u is a leap year', nyear)
else
   fprintf('%6u is not a leap year', nyear)
end
```

Output:

1975 is not a leap year

Remarks:

(1) In the *elseif* command (4th line), "&" means "AND". Both statements "(mod(nyaer,4) == 0)" and "(mod(nyear,100) ~= 0)" have to be true for Matlab to execute the command, "fprintf('%6u is a leap year', nyear)". Also commonly used in an *if* statement is "|" (a vertical line), which means "OR".

(2) The symbols "~=" in line 4 means "NOT EQUAL TO". There are 6 commonly used expressions to compare two numbers in an *if* command:

A > B	A is greater than B
A < B	A is less than B
A >= B	A is greater than or equal to B
A <= B	A is less than or equal to B
A == B	A equals B
A ~= B	A does not equal B

(3) The "mod(A,B)" function returns the remainder of A divided by B. For example, mod(7,2) = 1, mod(10,4) = 2, and mod(25,5) = 0. If A is divisible by B, mod(A,B) = 0. This is a very useful function in many applications related to numerical methods.

Ex 26 Combine looping and branching

```
sum1 = 0;
sum2 = 0;
N = 9
for k = 1:N
   sum1 = sum1+k;
   if (mod(k,3) == 0)
      sum2 = sum2+k;
   end
end
sum1
sum2
```

Output:

sum1 = 45
sum2 = 18

Remark: Sum1 = 1+2+3+4+5+6+7+8+9, while sum2 = 3+6+9.

Ex 27 The *while* loop

```
x = 3;
while (x < 100)
   x = x*3;
end
x
```

Output:

x = 243

Remark: One can think of a *while* loop as a combination of a *for* loop and an *if* statement. Here, the looping will keep going indefinitely as long as the condition, (x < 100), is satisfied. Therefore, the value of x progresses from 3, 9, 27, 81, to 243 when the loop is terminated.

Part 4. Array and Matrix

1. Assign the content of an array/matrix; Basic operations

Ex. 28 Assign the content of a (one-dimensional) array; Addition of two arrays

```
a = [2 12 25];
b = [3 7 4];
c = a+b
```

Output:

```
c = 5  19  29
```

Ex. 29 Assign the content of a matrix; Addition of two matrices

```
a = [3 4; 1 6];
b = [5 2; 11 7];
c = a+b
```

Output:

```
c =   8   6
     12  13
```

This program performs the following acts:

$$\boldsymbol{a} = \begin{bmatrix} 3 & 4 \\ 1 & 6 \end{bmatrix}$$

$$\boldsymbol{b} = \begin{bmatrix} 5 & 2 \\ 11 & 7 \end{bmatrix}$$

$$\boldsymbol{c} = \boldsymbol{a} + \boldsymbol{b} = \begin{bmatrix} 8 & 6 \\ 12 & 13 \end{bmatrix}$$

Ex. 30 Multiplication involving a scalar and an array (or a matrix)

```
a = [3 5; 1 4];
b = 2*a
```

Output:

```
b =   6   10
      2    8
```

Ex. 31 Element-by-element multiplication involving two 1-D arrays or two matrices of the same dimension

```
a = [2 3 5];
b = [2 4 9];
c = a.*b
```

Output:

```
c = 4   12   45
```

Remark: The period preceding the mathematical operation, "*", indicates that the operation will be performed element-by-element. In this case, the content of c is

```
c = [a(1)*b(1)  a(2)*b(2)  a(3)*b(3)]
```

Also, c is automatically assigned as a 1-D array with 3 elements

Ex. 32 Element-by-element multiplication of two matrices

```
a = [2 3; 1 4];
b = [5 1; 7 2];
c = a.*b
```

Output:

```
c = 10   3
     7   8
```

Ex. 33 Direct (not element-by-element) multiplication of two matrices

```
a = [2 3; 1 4];
b = [5 1; 7 2];
c = a*b
```

Output:

```
c = 31   8
    33   9
```

Remark: Observe how the outcome of this example differs from Ex. 32.

Ex. 34 Elementary functions with a vectorial variable

```
a = [2 3 5];
b = sin(a)
```

Output:

```
b = 0.9092   0.1411   -0.9589
```

Remark: The content of b is [sin(2) sin(3) sin(5)].

Ex. 35 Another example of elementary functions with a vectorial variable

```
a = [2 3 5];
b = 2*a.^2+3*a+4
```

Output:

```
b = 18  31  69
```

Remark: The content of b is

b = [2*(a(1))^2+3*a(1)+4 2*(a(2))^2+3*a(2)+4 2*(a(3))^2+3*a(3)+4].

Ex. 36 An efficient way to assign the content of an array

```
a = [0:0.5:4];
a
```

Output:

```
a = 0  0.5  1  1.5  2  2.5  3  3.5  4
```

Ex 37. Extracting the individual element(s) of a matrix

```
A = [3  5; 2  4];
c = A(2,2)+A(1,2)
```

Output:

```
c = 9
```

Remark: With the given A matrix, we have A(1,1) = 3, A(1,2) = 5, A(2,1) = 2, and A(2,2) = 4.

Ex. 38 Another example for the usage of index for a matrix

```
A = [3  5; 2  4];
norm1 = 0;
for m = 1:2
for n = 1:2
   norm1 = norm1+A(i,j)^2;
end
end
norm1 = sqrt(norm1)
```

Output:

```
norm1 = 7.348
```

Remark: This program calculates the Euclidean norm of the A matrix.

Ex. 39 Solving a system of linear equation

```
A = [4  1  2; 0  3  1; 0  1  2];
b = [17 ; 19 ; 13];
x = inv(A)*b
```

Output:

```
x  =  1
      5
      4
```

Remark: This program solves [**A**] **x** = **b**. The solution is obtained by **x** = [**A**]$^{-1}$ **b**.

Ex. 40 An alternative to Ex. 39

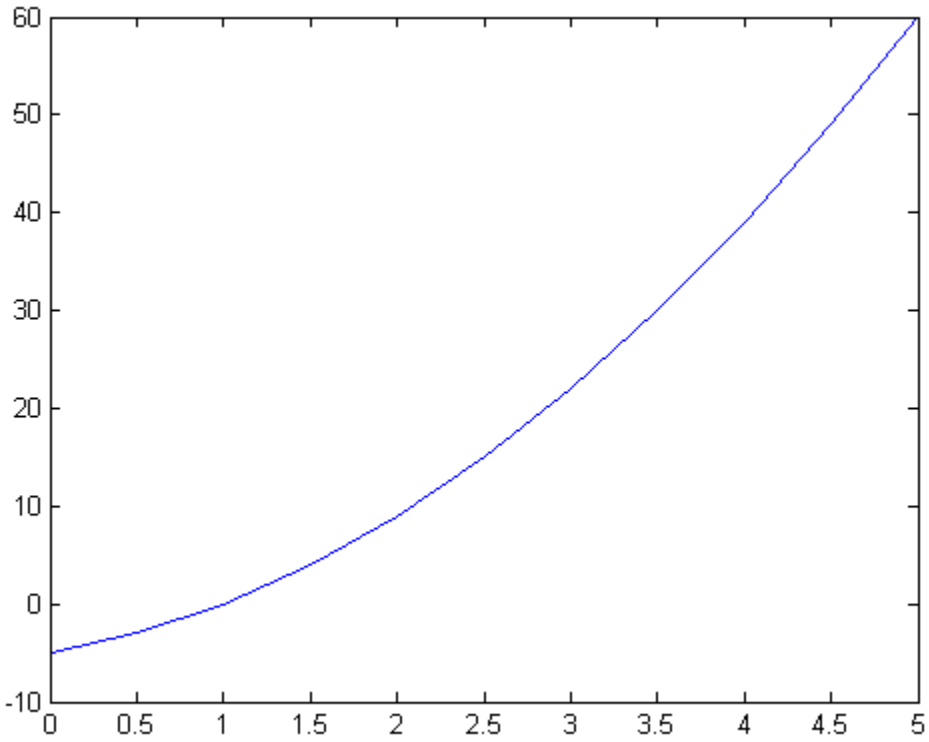
```
A = [4  1  2; 0  3  1; 0  1  2];
b = [17 ; 19 ; 13];
x = b\A
```

The output is the same as Ex. 39. Here, b\A is essentially inv(A)*b. (The "\" is called "back divide" in Matlab documentations.)

Part 5. Basic graphic applications

Ex. 41 A quick example of plot command: Draw a curve

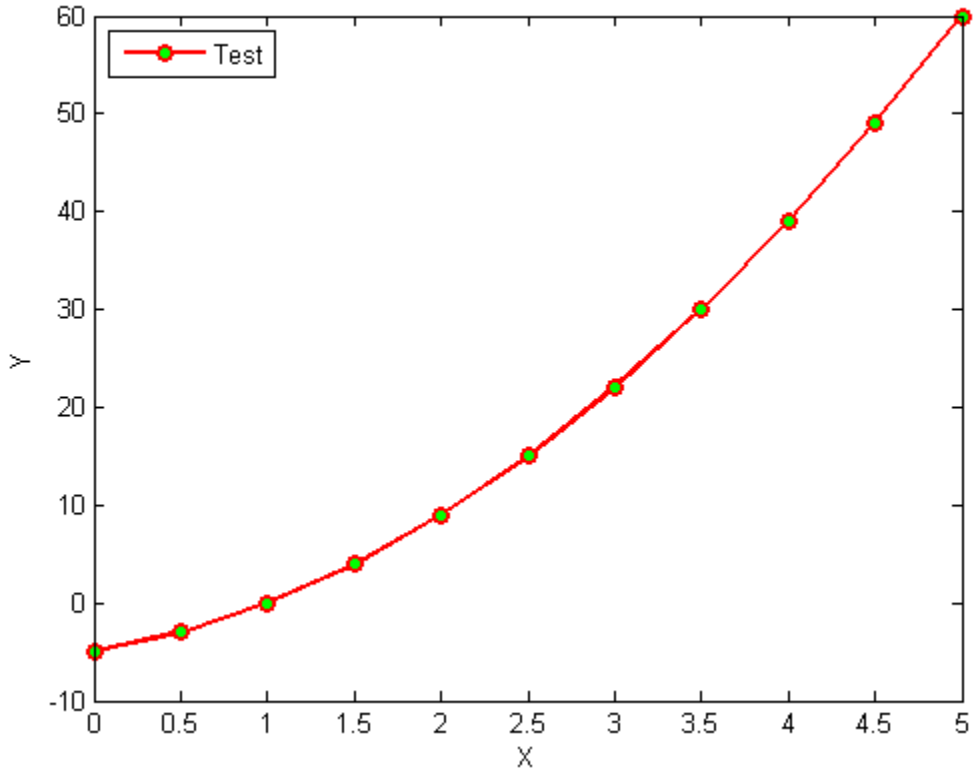
```
a = [0:0.5:5];
b = 2*a.^2 + 3*a -5;
plot(a,b)
```



Remarks:
(1) In "plot(a,b)", the array "a" should contain the data of the coordinate or "grid point) on the x-axis and "b" should be the corresponding values on the y-axis.
(2) After a plot is made, it can be further modified by using the interactive tool for graphics. For example, the labels of the x and y axes can be manually added to the plot.
(3) The plot can be saved in various formats (jpg, tif, eps, etc.).

Ex. 42 Refine the plot: Line pattern, color, and thickness

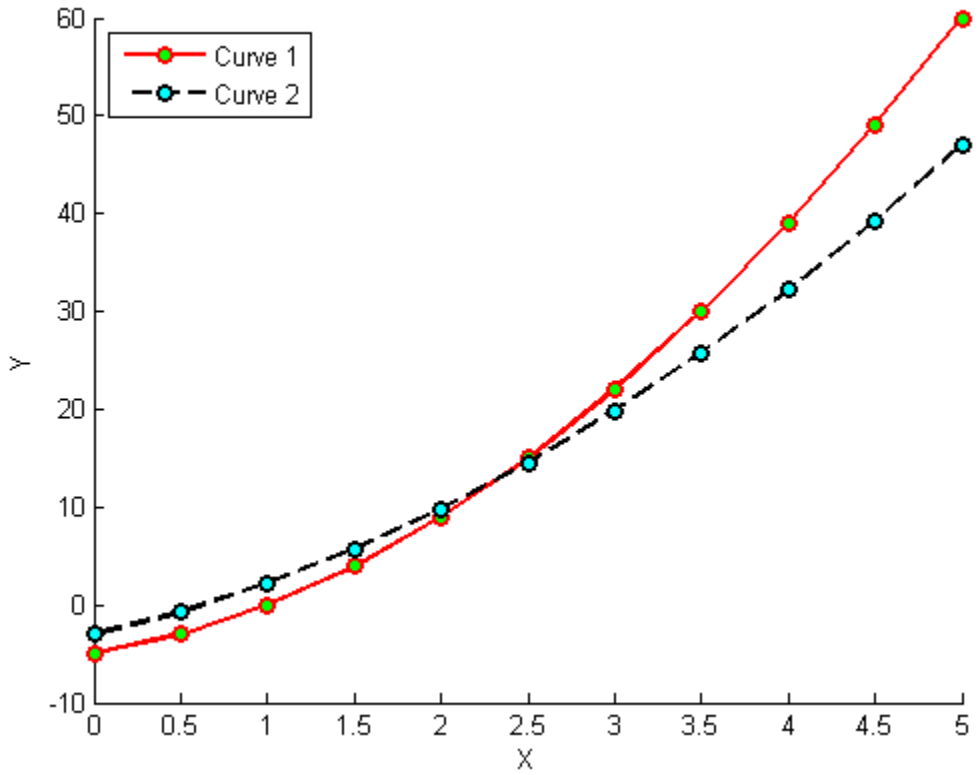
```
a = [0:0.5:5];
b = 2*a.^2 + 3*a -5;
plot(a,b,'-or','MarkerFaceColor','g','LineWidth',2)
xlabel('X'); ylabel('Y'); legend('Test','Location','NorthWest')
```



Remarks: The '-or' in the *plot* command set the line pattern. In this case, it's solid line with circular symbol. The circular symbol is filled with green color ('g' for 'MarkerFaceColor'). The legend of the plot is set to locate at teh upper-left corner ('Location'' set to 'NorthWest') inside the frame.

Ex. 43 Draw multiple curves

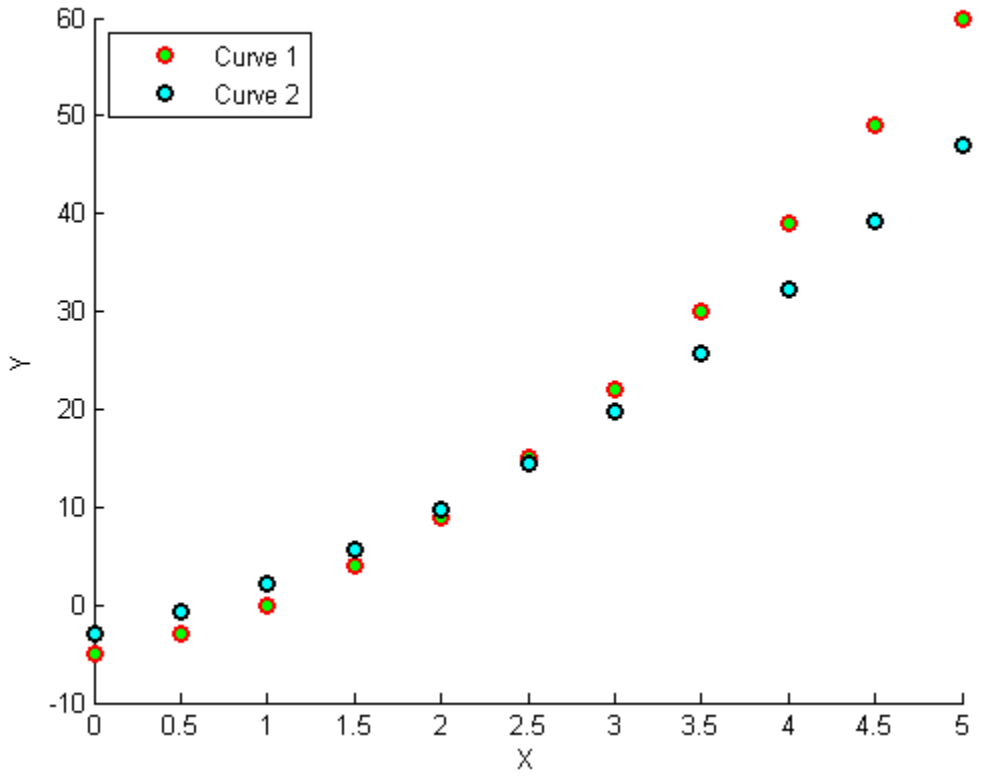
```
a = [0:0.5:5];
b = 2*a.^2 + 3*a -5;
c = 1.2*a.^2+4*a-3;
hold on
plot(a,b,'-or','MarkerFaceColor','g','LineWidth',2)
plot(a,c,'--ork,'MarkerFaceColor','c','LineWidth',2)
xlabel('X'); ylabel('Y'); legend('Curve 1','Curve 2','Location','NorthWest')
```



Remark: Without the "hold on" command, the second *plot* will override the first one and acts to erase the curve produced by the latter.

Ex. 44 Draw symbols

```
a = [0:0.5:5];
b = 2*a.^2 + 3*a -5;
c = 1.2*a.^2+4*a-3;
hold on
plot(a,b,'or','MarkerFaceColor','g','LineWidth',2)
plot(a,c,'ork,'MarkerFaceColor','c','LineWidth',2)
xlabel('X'); ylabel('Y'); legend('Curve 1','Curve 2','Location','NorthWest')
```



Ex. 45 Plot with multiple panels

```
a = [0:0.5:5];
b = 2*a.^2 + 3*a -5;
c = 1.2*a.^2+4*a-3;
subplot(1,2,1)
plot(a,b,'-or','MarkerFaceColor','g','LineWidth',2)
xlabel('X'); ylabel('Y'); legend('Curve ','Location','NorthWest')
subplot(1,2,2)
plot(a,c,'--ork,'MarkerFaceColor','c','LineWidth',2)
xlabel('X'); ylabel('Y'); legend('Curve 2','Location','NorthWest')
```