A Crash Course in MatLab

For Masters and other students

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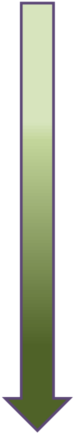
Today’s objective

Get comfortable playing with Matlab...

- Interacting with Matlab
- Enter Data
- Operations
- Some Commonly Used Functions
- Making Pretty Pictures
- M-Files and Scripts
- For, While, and If
- Solving ODEs



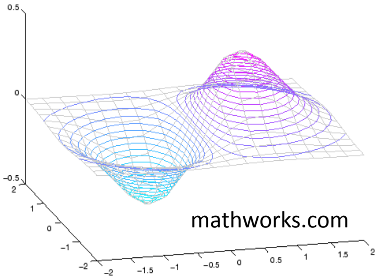
What is Matlab?

hibp.ecse.rpi.edu/~connor

- Matlab = Matrix Laboratory
- Problem-solving environment
- Designed for convenient *numerical* computations (e.g. matrix manipulation, differential eqns, stats, and graphics)
- Developed by Cleve Moler in 1970s as a teaching tool
- Now ubiquitous in education and industry

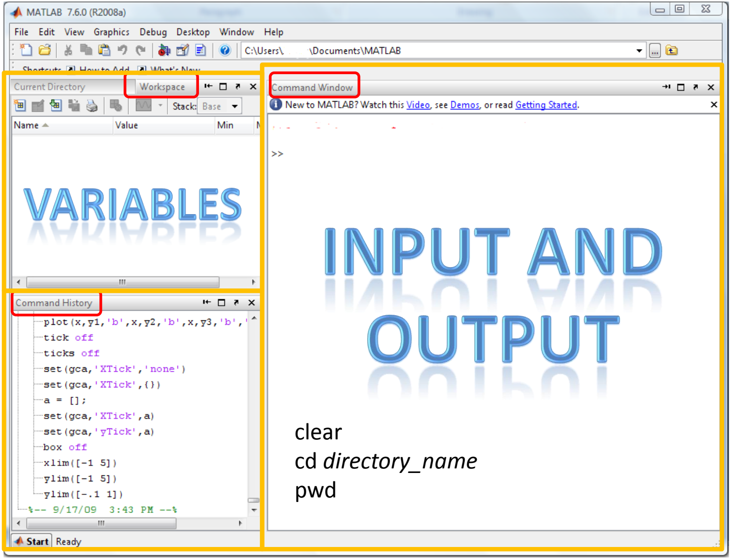
Why Matlab?

- Great tool for simulation and data analysis
- User-friendly interface
- Many easy to use built-in functions and tool boxes
- Easy visualization
- Easy to get help:
  - help *function_name*
  - lookfor *topic*
  - www.mathworks.com



mathworks.com

Interacting with Matlab



VARIABLES

```
plot(x,y1,'b',x,y2,'b',x,y3,'b','
tick off
ticks off
set(gca,'XTick','none')
set(gca,'XTick',{})
a = [];
set(gca,'XTick',a)
set(gca,'yTick',a)
box off
xlim([-1 5])
ylim([-1 5])
ylim([-.1 1])
%-- 9/17/09  3:43 PM --%
```

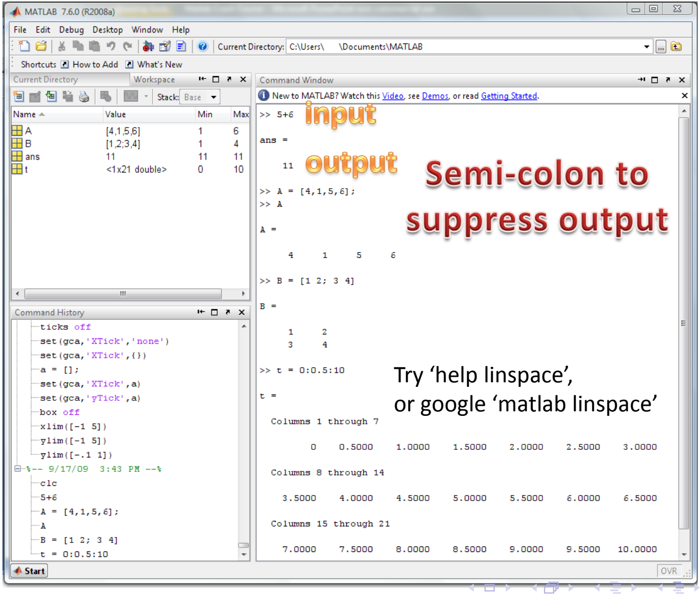
New to MATLAB? Watch this Video, see Demos, or read Getting Started.

```
>>
```

INPUT AND OUTPUT

clear
cd *directory_name*
pwd

Entering Data


MATLAB 7.6.0 (R2008a)
File Edit Debug Desktop Window Help
Current Directory: C:\Users\ \Documents\MATLAB
Shortcuts How to Add What's New
Current Directory
Workspace
Stack: Base
Command Window
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Command History
Start
OVR

Name	Value	Min	Max
A	[4,1,5,6]	1	6
B	[1,2;3,4]	1	4
ans	11	11	11
t	<1x21 double>	0	10

```
ticks off
set(gca,'XTick','none')
set(gca,'XTick',{})
a = [];
set(gca,'XTick',a)
set(gca,'yTick',a)
box off
xlim([-1 5])
ylim([-1 5])
ylim([-.1 1])
%-- 9/17/09  3:43 PM --%
clc
5+6
A = [4,1,5,6];
A
B = [1 2; 3 4]
t = 0:0.5:10
```

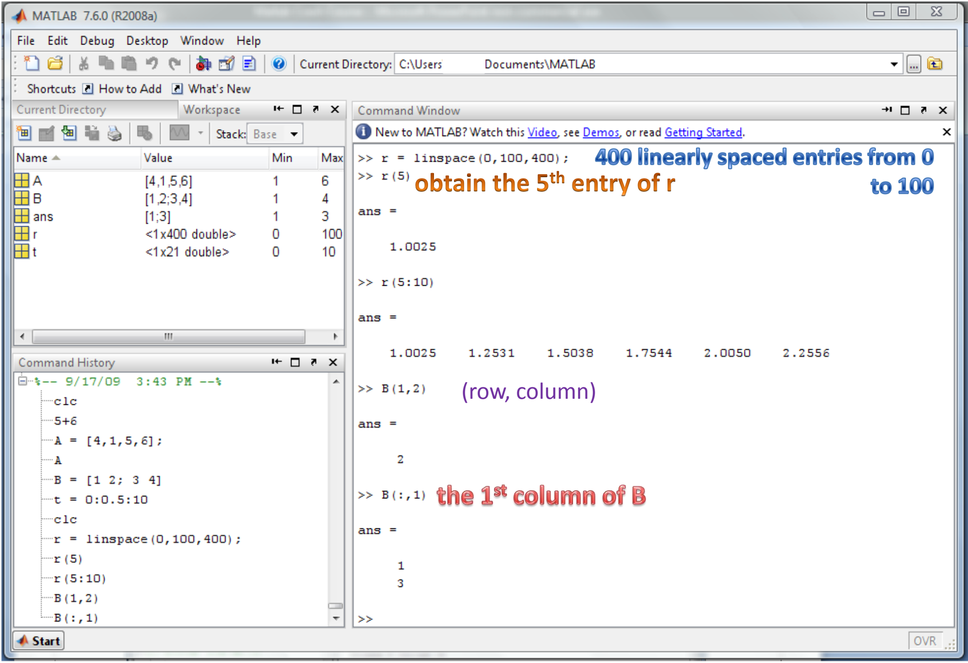
```
>> 5+6

ans =

    11

>> A = [4,1,5,6];
>> A

A =

     4     1     5     6

>> B = [1 2; 3 4]

B =

     1     2
     3     4

>> t = 0:0.5:10

t =

  Columns 1 through 7

         0    0.5000    1.0000    1.5000    2.0000    2.5000    3.0000

  Columns 8 through 14

    3.5000    4.0000    4.5000    5.0000    5.5000    6.0000    6.5000

  Columns 15 through 21

    7.0000    7.5000    8.0000    8.5000    9.0000    9.5000   10.0000
```

input

output

Semi-colon to suppress output

Try ‘help linspace’,
or google ‘matlab linspace’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Start
OVR

Name	Value	Min	Max
A	[4,1,5,6]	1	6
B	[1,2;3,4]	1	4
ans	[1;3]	1	3
r	<1x400 double>	0	100
t	<1x21 double>	0	10

```
%-- 9/17/09  3:43 PM --%
clc
5+6
A = [4,1,5,6];
A
B = [1 2; 3 4]
t = 0:0.5:10
clc
r = linspace(0,100,400);
r(5)
r(5:10)
B(1,2)
B(:,1)
```

```
>> r = linspace(0,100,400);
>> r(5)

ans =

    1.0025

>> r(5:10)

ans =

    1.0025    1.2531    1.5038    1.7544    2.0050    2.2556

>> B(1,2)

ans =

     2

>> B(:,1)

ans =

     1
     3

>>
```

400 linearly spaced entries from 0 to 100

obtain the 5th entry of r

(row, column)

the 1st column of B

Some Frequently Used Commands

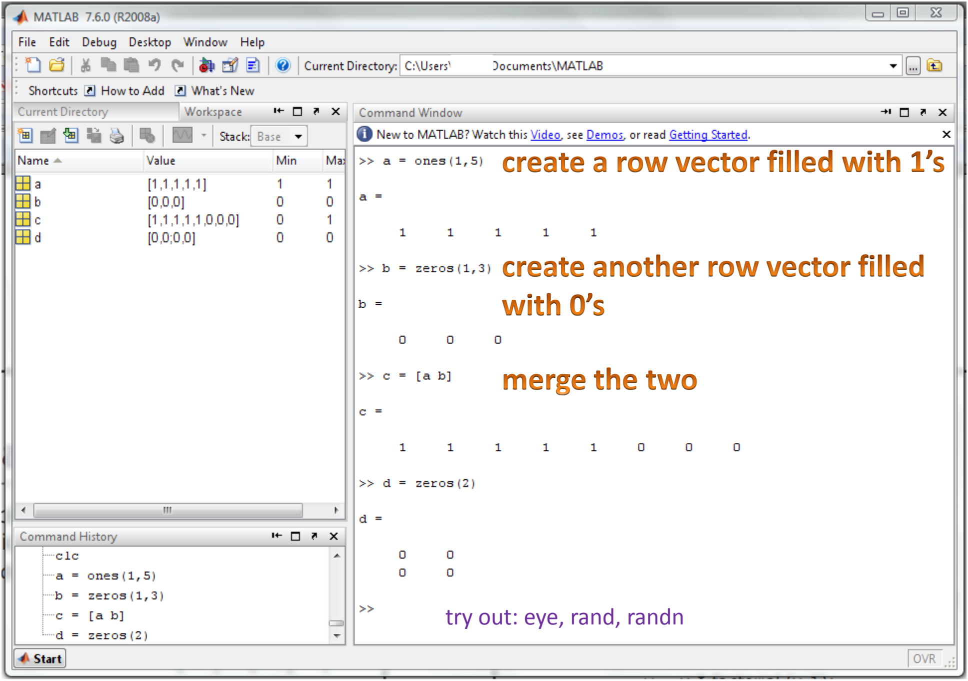
- To show variable: `who` and `whos`
- To get help on any command: `help any_command`
- To get documentation of any command: `doc any_command`
- For clearing screen: `cls`
- For removing variables from memory: clear variable_name

Entering data (in workspace/command line):

- Quite simple 0 : `a = 2`
- Semicolon, stops printing values for variables. : `a = 2;`
- Vectors in brackets [ ] : `vec = [1 2 3];`
- Matrices, as combination of vectors:`mat = [1 2 3;4 5 6;7 8 9]`
- Using existing arrays(vectors and matrices); for e.g. using first row of above matrix `mat(1,:)`

Some Functions:

- To get vectors(or matrices) of elements 0 : `zeros(m,n)`
- To get vectors(or matrices) of elements 1 : `ones(m,n)`
- Sum, Subtract, Multiplication and Division : `+, -, *, /` for all objects.
- Point-wise operations: `.* , ./ and so on`
- Exponential, Logarithm and other functions: `exp, log,`
- Formatting numbers: for e.g. `format short, format long, and others`



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Command History
Start
OVR

Name	Value	Min	Max
a	[1,1,1,1,1]	1	1
b	[0,0,0]	0	0
c	[1,1,1,1,1,0,0,0]	0	1
d	[0,0;0,0]	0	0

```
>> a = ones(1,5)

a =

     1     1     1     1     1

>> b = zeros(1,3)

b =

     0     0     0

>> c = [a b]

c =

     1     1     1     1     1     0     0     0

>> d = zeros(2)

d =

     0     0
     0     0

>>
```

create a row vector filled with 1's

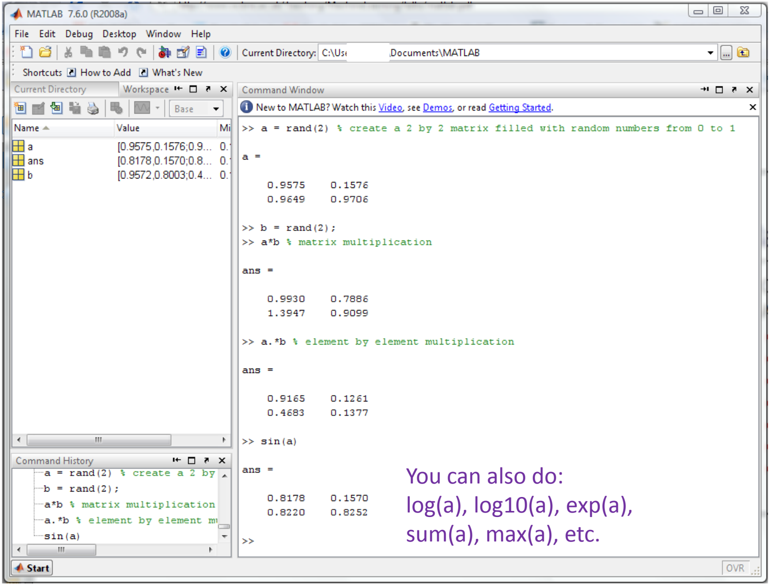
create another row vector filled with 0's

merge the two

try out: eye, rand, randn

```
clc
a = ones(1,5)
b = zeros(1,3)
c = [a b]
d = zeros(2)
```

Operations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Command History
Start
OVR

Name	Value	Mi
a	[0.9575,0.1576;0.9...	0.
ans	[0.8178,0.1570;0.8...	0.
b	[0.9572,0.8003;0.4...	0.

```
>> a = rand(2) % create a 2 by 2 matrix filled with random numbers from 0 to 1

a =

    0.9575    0.1576
    0.9649    0.9706

>> b = rand(2);
>> a*b % matrix multiplication

ans =

    0.9930    0.7886
    1.3947    0.9099

>> a.*b % element by element multiplication

ans =

    0.9165    0.1261
    0.4683    0.1377

>> sin(a)

ans =

    0.8178    0.1570
    0.8220    0.8252

>>
```

Command History:

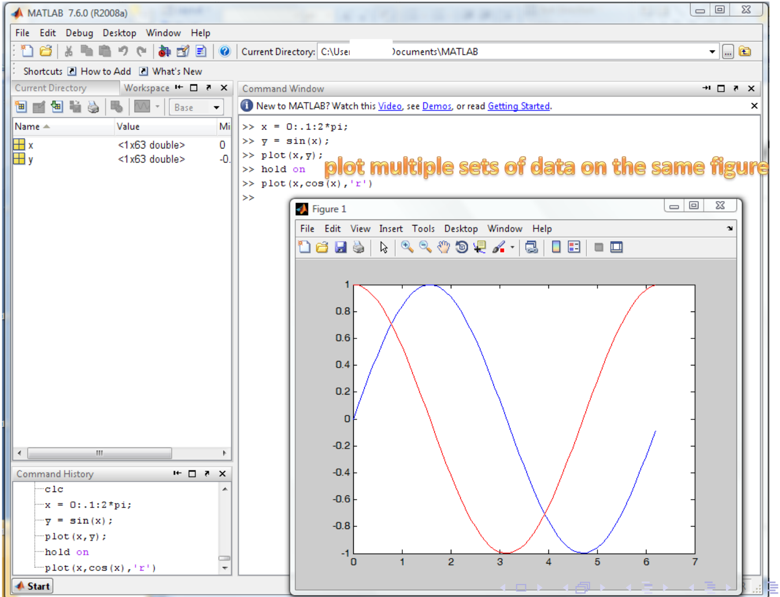
```
a = rand(2) % create a 2 by
b = rand(2);
a*b % matrix multiplication
a.*b % element by element mu
sin(a)
```

You can also do:
log(a), log10(a), exp(a),
sum(a), max(a), etc.

Plotting :

- To start blank figure : `figure`
- plot : `plot(y,x,'OPTIONS')`, where y and x are vectors(or matrices) and options are like line style, line color, etcetera.

Plotting Data / Making Pretty Pictures



plot multiple sets of data on the same figure

```
>> x = 0:.1:2*pi;
>> y = sin(x);
>> plot(x,y);
>> hold on
>> plot(x,cos(x),'r')
>>
```

Name	Value	Mi
x	<1x63 double>	0
y	<1x63 double>	-0.

Command History

```
clc
x = 0:.1:2*pi;
y = sin(x);
plot(x,y);
hold on
plot(x,cos(x),'r')
```

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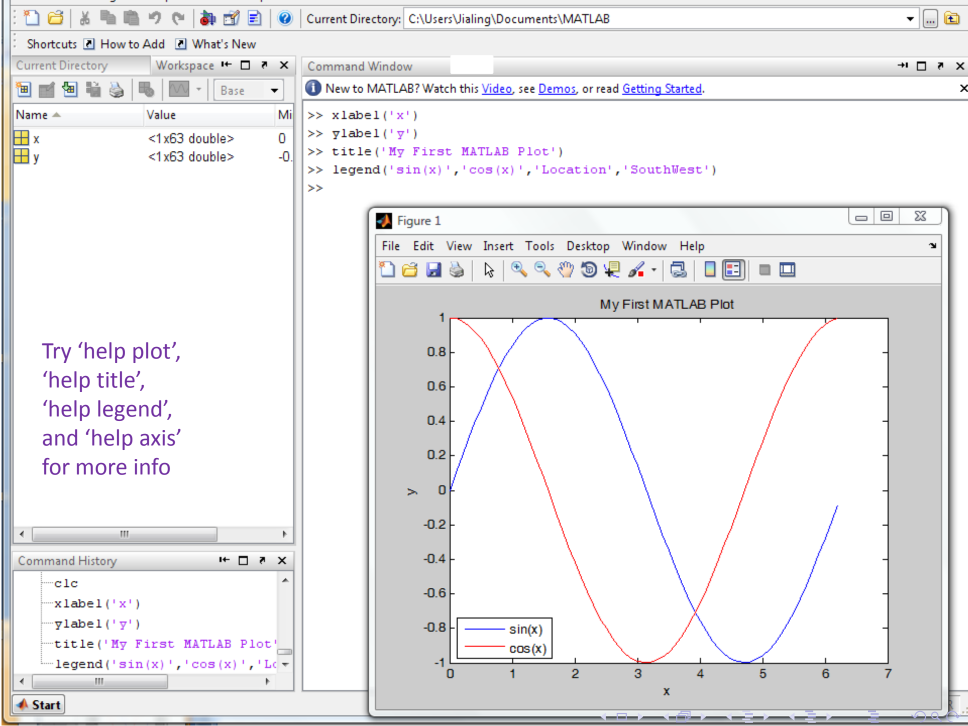
Current Directory: C:\Use Documents\MATLAB



Current Directory: C:\Users\Jialing\Documents\MATLAB

New to MATLAB? Watch this Video, see Demos, or read Getting Started.

Name	Value	Mi
x	<1x63 double>	0
y	<1x63 double>	-0.

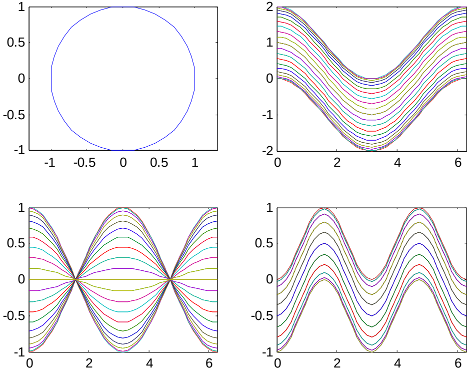
```
>> xlabel('x')
>> ylabel('y')
>> title('My First MATLAB Plot')
>> legend('sin(x)','cos(x)','Location','SouthWest')
>>
```

```
clc
xlabel('x')
ylabel('y')
title('My First MATLAB Plot'
legend('sin(x)','cos(x)','Lc
```

Try ‘help plot’, ‘help title’, ‘help legend’, and ‘help axis’ for more info

More About Plotting

```
t = 0:pi/20:2*pi;
[x,y] = meshgrid(t);   % look up meshgrid

subplot(2,2,1)    % creates a 2x2 array of plots, and plot in the first subplot
plot(sin(t),cos(t))
axis equal   % this is a parametric plot

subplot(2,2,2)
z = sin(x)+cos(y);    % z is a matrix
plot(t,z)
axis([0 2*pi -2 2])     % plotting each column of z
                        % versus t

subplot(2,2,3)
z = sin(x).*cos(y);
plot(t,z)
axis([0 2*pi -1 1])

subplot(2,2,4)
z = (sin(x).^2)-(cos(y).^2);
plot(t,z);
axis([0 2*pi -1 1])
```



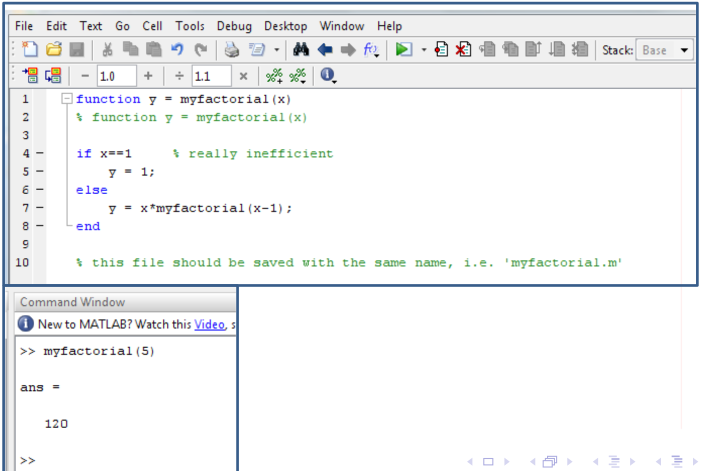
```
% for 3-D plotting, try mesh, surf, surfl, waterfall, etc
```

Creating files and M-Files :

- creat files in editor : `edit newfile.m`
- Functions in m-files : `ones(m,n)`

M-Files and Functions

- Let’s make our own functions
- To start the editor, type ‘edit’

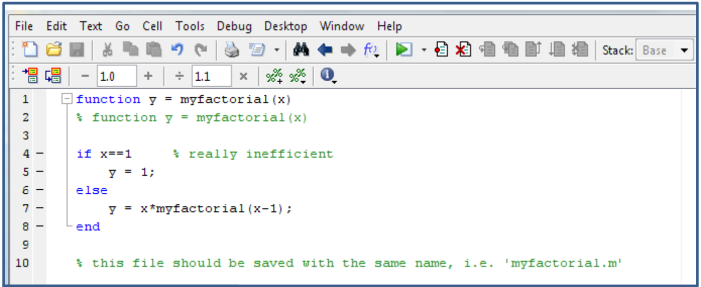


```
function y = myfactorial(x)
% function y = myfactorial(x)

if x==1     % really inefficient
    y = 1;
else
    y = x*myfactorial(x-1);
end

% this file should be saved with the same name, i.e. 'myfactorial.m'
```

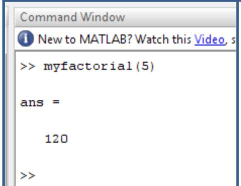
```
>> myfactorial(5)

ans =

   120

>>
```

M-Files and Functions

- Local workspace and Scoping
- To make variables global: global *variable_name*



```
function y = myfactorial(x)
% function y = myfactorial(x)

if x==1     % really inefficient
    y = 1;
else
    y = x*myfactorial(x-1);
end

% this file should be saved with the same name, i.e. 'myfactorial.m'
```



New to MATLAB? Watch this Video, s

```
>> myfactorial(5)

ans =

   120

>>
```

For, if and while loops :

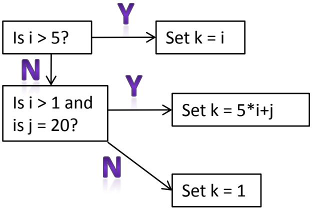
- Several built-in functions for e.g. : `ode23, ode45, ode23s, ode113 etcetera`
- Lot of other ode solver function in external libraries.

For, While, and If

```
for m = 1:100
        num = 1/(m+1)
end
-----------------------------
% find all the powers
% of 2 below 10000
while num < 10000
        num = 2^i;
        v = [v; num];
        i = i+1;
end
-----------------------------
i = 6; j = 21;
if i > 5
        k = i;
elseif (i > 1) & (j == 20)
        k = 5*i+j;
else
        k = 1;
end
```

A for loop

A while loop



• And:	a & b
• Or:	a | b
• Not-equal:	a ~=b
• Equal:	a == b

Solving Differential Equations numerically :

- Several built-in functions for e.g. : `ode23, ode45, ode23s, ode113 etcetera`
- Lot of other ode solver function in external libraries.

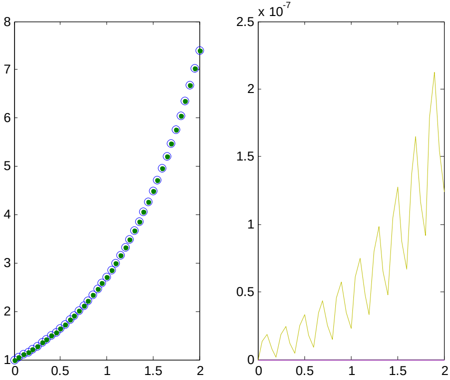
Solving ODEs

- A very simple case: $\frac{dy}{dt} = y(t) \qquad 0 \le t \le 2 \qquad y(0) = 1$

```
function dy = simpleode(t,y)
dy = y;  % save as simpleode.m
```

- Type in command line:

```
[t y] = ode45(@simpleode, [0, 2], [1]);
subplot(1,2,1),plot (t,y,'o',t,exp(t),'.')
subplot(1,2,2),plot(t,(y-exp(t))/exp(t))
```



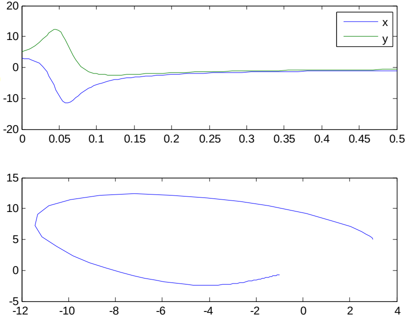
Solving ODEs

- A system of eqns:

$$\frac{dx}{dt} = 2x - y + 3(x^2 - y^2) + 2xy \qquad 0 \le t \le \frac{1}{2}$$

$$\frac{dy}{dt} = x - 3y - 3(x^2 - y^2) + 3xy \qquad y(0) = 3, x(0) = 5$$

```
function xdot = aode(t,y)
% y(1) = x
% y(2) = y
xdot = zeros(2,1); % initialize the xdot vector
xdot = [2*y(1)-y(2)+3*(y(1)^2-y(2)^2)+2*y(1)*y(2)
        y(1)-3*y(2)-3*(y(1)^2-y(2)^2)+3*y(1)*y(2)];
%save as aode.m
```



- Type in command line:

```
[t,y] = ode45(@aode,[0,.5],[3;5]);
subplot(2,1,1),plot(t,y)
subplot(2,1,2),plot(y(:,1),y(:,2)) % plot the phase portrait
```

Solving ODEs

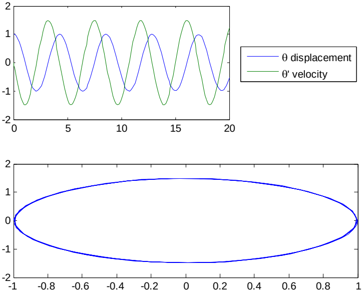
- A second order system: $$\ddot{\theta}+\omega^2\sin\theta=0 \qquad \begin{array}{l}\theta(0)=1\\ \dot{\theta}(0)=0\end{array}$$
- First, convert to a system of two first-order equations, *by hand*.

  let $\begin{array}{l}u_1=\theta\\ u_2=\dot{\theta}\end{array}$, then $\begin{bmatrix}\dot{u}_1\\ \dot{u}_2\end{bmatrix}=\begin{bmatrix}u_2\\ -\omega^2\sin(u_1)\end{bmatrix}$

```
function udot = pend(t,u,omega)
udot = zeros(2,1)
udot = [u(2); -omega^2*sin(u(1))];
%save as pend.m
```

- Type in command line:

```
%omega = 1.56
[t, y] = ode45(@pend,[0 20],[1;0],[],1.56);
subplot(2,1,1),plot(t,y)
subplot(2,1,2),plot(y(:,1),y(:,2)) % plot the phase portrait
```


θ displacement
θ' velocity