

Introduction to Scientific and Engineering Computing, BIL108E

INTRODUCTION TO SCIENTIFIC & ENGINEERING COMPUTING BIL 108E, CRN24023

Dr. S. Gökhan Karaman

Technical University of Istanbul

February 15, 2010



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USING MATLAB

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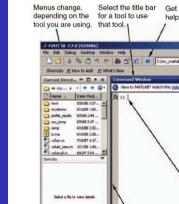
Double click the Matlab icon.

To start from UNIX.

type matlab at the shell prompt.

MATLAB Desktop

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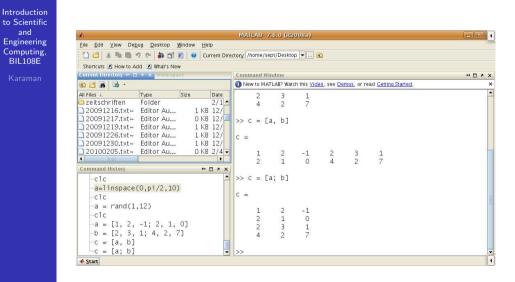
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MATLAB Desktop





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USING MATLAB

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To end Matlab session,

- From File pulldown menu, select Exit MATLAB.
- Enter exit or quit at the command prompt



COMMAND LINE

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- $\blacksquare \gg$ indicates the command prompt
- You can edit a MATLAB command before pressing Enter(executing or running) by using various combinations of the Backspace, Left-arrow, Right-arrow, and Del keys.
- You can select (and edit) commands you have entered using Up-arrow and Down-arrow.
- MATLAB has a useful editing feature called smart recall. Just type the first few characters of the command you want to recall. For example, type the characters 2^* and press the Up-arrow key. This recalls the most recent command starting with 2*.



ARITHMETICS

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Matlab command prompt can be used as a calculator.

>>	8 + 9
>>	24 - 12
>>	8 ^ 2
>>	1 / 16
>>	16 \ 1

Backslash means the denominator is to the left of the symbol.



ARITHMETICS

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Period in front of the operators means that the operation is done with single numbers.

>> 2	.* 6
>> 1	./ 8
>> 3	.^ 4
>> 5	.^ 2

It is important, when we deal with array of numbers.

ARITHMETIC OPERATORS

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Matlab Operations

Symbol	Operation	Example	Answer
+	Addition	z = 4 + 2	z = 6
-	Subtraction	z = 4 - 2	z = 2
/	Right division	z = 4/2	z = 2
1	Left division	$z = 2 \setminus 4$	z = 2
*	Multiplication	z = 4 * 2	z = 8
^	Exponentiation	$z = 4^{\wedge}2$	z = 16
Functions such as:	square root log2	z = sqrt(4)	z = 2
sqrt, log		$z = \log 2(4)$	z = 2



RELATIONAL OPERATORS

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Operator Name	Operator Symbol	EXAMPLE
less than	<	x <y< td=""></y<>
less than equal to	<=	a<=22
equal to	==	x==100
not equal to	~=	x~=10
greater than equal to	=>	pi=>3
greater than	>	c>100



OPERATOR PRESEDENCE

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Precedence	Operators
1.	(,)
2.	^, .^, ', .' (pure transpose)
3.	+ (unary plus), -(unary minus),
	~ (NOT)
4.	*, /, .*, ./, .\
5.	+ (addition), - (subtraction)
6.	:
7.	>, <, >=, <=, ==, ~=
8.	& (AND)
9.	(OR)

Operator presedence from this table and from left to right.

PRECISION FORMATS

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Precision Formats

MATLAB Instruction	Display	Numerical Output exp(1)
format short	4 decimal digits (default)	2.7183
format long	16 decimal digits	2.71828182845905
format short e	4 decimal digits plus exponent	2.7183e+000
format long e	15 decimal digits plus exponent	2.71828182845904e+000
format bank	2 decimal digits	2.72
format +	+, -, 0 (positive, negative, and zero)	+
format hex	Hexadecimal	4005bf0a8b14576a
format rat	Rational approximation	1457/536
format compact	Suppress extra line-feeds	2.7183
format loose	Puts the extra line-feeds back in	2.7183



NUMBERS

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Numbers can be defined in the decimal form

Example;

1.732050808, -24, 256.0

In scientific notation e or E could be used to define the exponent. Exponent should be an integer.

The mantissa is multiplied by the power of 10 indicated by the exponent. Example;

12.35e-3 12.35×10^{-3}

DATA TYPES

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Default numeric data type is double precision.

Matlab has 14 data types.

Examples:

integer, unsigned integer, string, single precision

SPECIAL VALUES

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Matlab warns you in case of errors, but still gives answer.

Example;

- **1**/0
- Inf
- **0**/0 NaN

You can use these symbols in any calculation.



VARIABLES

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Variable Naming Rules

- It may consist only of the letters a-z, the digits 0-9, and the underscore _.
- It must start with a letter
- The name will be as long as you like but Matlab remembers only the first 63 characters
- Matlab is case sensitive, upper and lower case variables are not the same.

Examples;

r2d2, x3po, luke_filewalker RIGHT

_2d, luke-filewalker, balance\$ WRONG

Good Naming Techniques

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Camel Caps (dayOfTheWeek, milleniumBug, StarWars)

using underscore (star_wars, day_of_the_week)



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RESERVED VARIABLES

List of Reserved Variable Names

Variable	Description
ans	Temporary variable that stores the most recent answer.
computer	Returns the computer type.
version	MATLAB version.
ver	Returns the information about the license and version of the MATLAB package installed in your computer.
license	License information.
pi	The number $\pi = 3.14159$
exp(1)	The value of $e = 2.71$
eps	Represents the accuracy of floating point, the smallest possible positive number with a magnitude of the order of 10 ⁻¹⁰ .
realmin	The smallest real positive number.
realmax	The largest real positive number.
bitmax	The largest positive integer, magnitude of $2^{53} - 1$.
flops	Counts of the floating-point operations. flop(0) starts the count of all algebraic operations such as $+, -, *, /$.
inf	Represents infinity, (1/0).
nan	Not a number, undefined $(0/0)$.
i or j	The value of $\sqrt{-1}$. Denotes the imaginary part of a complex number.
input	Accepts information via keyboard.
date	Represents the current date as a string. For example, 25-Jul-00.
clock	Represents the current date and time as YYMMDDHHMMSS.
beep	Executes a beep sound.
etime (T _f , T _l)	Calculates elapse time in seconds between T_I (initial) and T_f (final). T_I and T_f are in vector form consistins of six elements (year month day hour minute second
tic, toc	Measures the time between the tic and the toc. The tic starts the stopwatch and the toc stops the stopwatch and outputs the elapsed time.
cputime	Total time of MATLAB used in seconds.
Pause	Stops executing a program momentarily.
Pause(n)	Stops executing a program during n seconds.

THE STATEMENT IS

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To do arithmetic operations with the variables we should assign values to variables.

>> a = 7; >> b = 8; >> c = a + b; >> t = 12; r = 32; >> u = t * r;

VARIABLES

Several commands can be seperated by comma or semicolon and output disabled with semicolon.

whos represent the locally defined variables and commands in



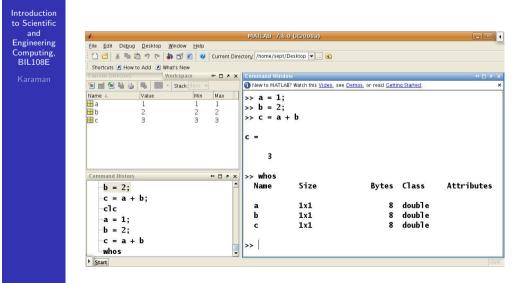
VARIABLES

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Names should not duplicate with built-in functions.

- >> pi = 7; >> sqrt(pi);
- pi has a different value then expected.

MATLAB Desktop



VARIABLES

>> who

>> whos

>> whos

>> clear pi

>> sqrt(pi)

the workspace with size info.

clear deletes the defined variable

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VARIABLES

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save filename

load filename

These commands are used to save and load the variables in the current workspace to a file.



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GENERAL FUNCTIONS

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date, calendar

- **clc** clear command window
- **clf** clear figure window

help



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BUILT-IN FUNCTIONS

MATLAB offers a wealth of built-in math functions that can be quite helpful for many computational problems

- Elementary MATLAB functions (help elfun)
 - Trigonometric functions
 - Exponential functions
 - Complex functions
 - Rounding and remainder functions
- Specialized MATLAB functions (help specfun)
 - Specialized math functions
 - Number theoretic functions
 - Coordinate transformations

and

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• <u>Start</u>				Toyn.



MATHEMATICAL FUNCTIONS

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abs	Absolute value
acos, acosh	Inverse cosine and inverse hyperbolic cosine
acot, acoth	Inverse cotangent and inverse hyperbolic cotangent
acsc, acsch	Inverse cosecant and inverse hyperbolic cosecant
angle	Phase angle
asec, asech	Inverse secant and inverse hyperbolic secant
asin, asinh	Inverse sine and inverse hyperbolic sine
atan, atanh	Inverse tangent (two quadrant) and inverse hyperbolic tangent
atan2	Inverse tangent (four quadrant)
bessel	Bessel function
ceil	Round up
conj	Complex conjugate
cos, cosh	Cosine and hyperbolic cosine
cot, coth	Cotangent and hyperbolic cotangent
csc, csch	Cosecant and hyperbolic cosecant

Introduction to Scientific and Engineering Computing, BIL108E



MATHEMATICAL FUNCTIONS cont'd

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erf	Error function
exp	Exponential
fix	Round toward zero
floor	Round down
gamma	Gamma function
imag	Imaginary part
log	Natural logarithm
log2	Dissect floating point numbers into exponent and mantissa
log10	Common logarithm
mod	Modulus (signed remainder after division)
rat	Rational approximation
real	Real part
rem	Remainder after division
round	Round toward nearest integer
sec, sech	Secant and hyperbolic secant
sign	Signum function
sin, sinh	Sine and hyperbolic sine
sqrt	Square root
tan, tanh	Tangent and hyperbolic tangent



LINEAR EQUATIONS

Introduction to Scientific and Engineering

BIL108E Karaman

Computing,

2x - y = 4

$$-x+2y=3$$

$$\left(\begin{array}{c}2\\-1\end{array}\right)x+\left(\begin{array}{c}-1\\2\end{array}\right)y=\left(\begin{array}{c}4\\3\end{array}\right)$$

Column picture

Scalars are not enough to define this kind of data.

VECTORS

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A vector is an ordered list of numbers (one-dimensional). In MATLAB they can be represented as a row-vector or a column-vector $(1 \times n)$ or $(n \times 1)$.

Simple vector definition;

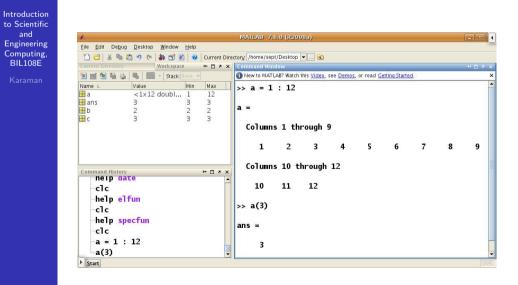
COLON : is used to define row vectors in Matlab.

>> a = 1 : 12; >> size(a)

size command shows dimension of the variable, here the size of vector *a*.



MATLAB Desktop





VECTORS

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a = 1 a(3) clc): 0.1 : 12;			



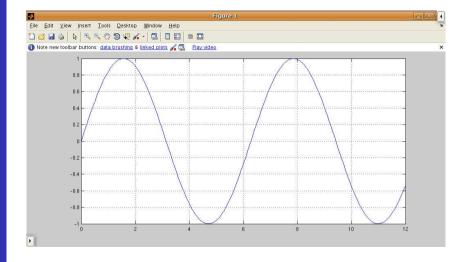
Engineering

Computing,

BIL108E

VECTORS

Introduction to Scientific



EXAMPLES

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Example; Eile Edit Debug Desktop Window Help 🚹 🗃 🔏 ங 🛱 🤊 🍽 💩 🛒 🖹 😮 Current Directory: /home/sept/Desktop 👻 ... 😢 Workspace 🏨 🖬 🛪 🗙 Command Windo 🛅 📷 🝓 🍇 🖏 🔜 - Stack: 845 New to MATLAB? Watch this <u>Video</u>, see <u>Demos</u>, or read <u>Getting Started</u>. Name ∠ Value Min Max >> [x y] = meshgrid(-12 : 0.5 : 12); 🖽 a <1×12 doubl... 1 12 >> r = sqrt(x.^2 + y.^2) + eps; 🗄 ans 3 3 3 >> z = sin(r) ./ r; Шb 2 >> mesh(z) H c Hr <49x49 dou... 2.2... 16.... Π× <49x49 dou... -12 12 <49x49 dou... -12 12 ⊞y ⊞z <49x49 dou... -0.... 1 Command History X 5 🗆 🕂 x = 0 : 0.1 : 12;y = sin(x);plot(x, y), grid clc [x y] = meshgrid(-12 : 0.5 : $r = sqrt(x.^{2} + y.^{2}) + eps;$ z = sin(r) ./ r; Þ • <u>Start</u>

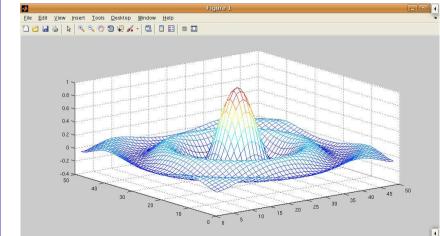
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Engineering

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EXAMPLES

Introduction to Scientific





EXAMPLES

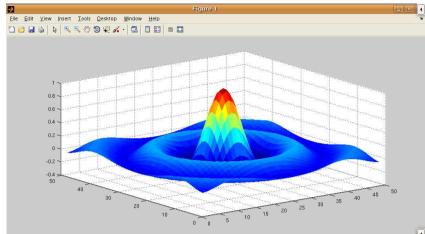
Introduction to Scientific and Engineering Computing, BIL108E

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$z = \sin(r) . / r$	r =			
	r =	sin(r) ./ r;		



EXAMPLES

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A SAMPLE STATEMENT

EXAMPLES

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Given : Balance 2000 USD, 12% rate per year Find : Bank Balance after 3 years? Formula : $balance(1 + r)^n$ First write down a rough algorithm.

- **1** Get the data into Matlab.
- **2** Calculate the balance after 3 years
- **3** Display the new balance



EXAMPLES

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balance = 2000; % USD rate = 0.12; % bank rate time = 3; % years balance = balance * (1 + rate)^time; disp('New balance:'); disp(balance)



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Introduction

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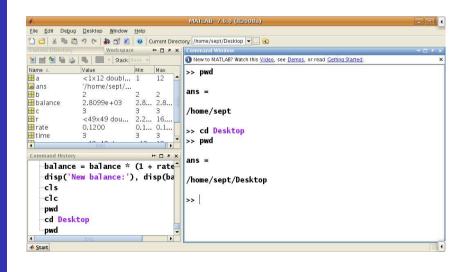
RUNNING SCRIPT FILES

Use file extension .mat for Workspace files and can be opened from Matlab Desktop File menu. Use file extension .m for function files pwd shows the current directory of matlab

- cd change directory to run the script file
- change directory with Matlab desktop Directory Browser.

MATLAB Desktop

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linspace FUNCTION



The function linspace creates a vector of equally spaced values.

Example;

linspace(0 , pi/2, 20)

creates a vector with the size of 1×20 from 0 to pi/2



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TRANSPOSE OF A VECTOR

Introduction to Scientific and

Engineering

Computing, BIL108E

- a = [1 2 3 5 8 13] is a row vector.
- "[" and "]" used to define a vector.

To generate the column vector, transpose the vector.

b = [1 2 3 5 8 13], (') apostrophe is used to transpose vector a. Size of a is $1 \times n$

Size of b is $n \times 1$

In mathematics a column vector is shown as a^i and a row vector is shown as a_j . A matrix could be shown as a_{ij} , ora^i_i

SUBSCRIPT

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rand(i,j) command is used for creating a random variable
matrix with values between 0 and 1.

a=rand(1,12) creates a 1x12 row vector.

a(3) gives the third element of the vector

a(3:5) gives the elements between 3 and 5



to

MATLAB Desktop

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a = rand(1, 10)	1000	0.1270	0.9134			
a(3:4)							

BRANIE CANTON

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A matrix is a rectangular array of numbers (multidimensional). In MATLAB, a two-dimensional matrix is defined by its number of rows and columns $(n \times m)$ or $(m \times n)$.

A matrix can be created like a vector.

Examples;

MATRIX

- a = [1 2 -1; 2 1 0]
- **b** = [2, 3, 1 ; 4, 2, 7]

A matrix can also be constructed from other matrices.

- \blacksquare c = [a , b]
- c = [a ; b]

MATLAB Desktop

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MATLAB Desktop

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Capturing Output

Introduction to Scientific and Engineering Computing, BIL108E

diary FILENAME

It creates a file with the name *FILENAME* and appends all the output to this file till we end it with the command

diary off



VERTICAL MOTION UNDER GRAVITY

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EXAMPLE: VERTICAL MOTION UNDER GRAVITY

If a stone is thrown vertically upward with an initial speed u its vertical displacement s after an elapsed time t is given by the formula $s = ut - gt^2/2$, where g is the acceleration due to gravity. Air resistance is ignored.

We would like to compute the value of s over a period of about 12.3 seconds at intervals of 0.1 seconds, and plot the distance versus time graph over this period.



VERTICAL MOTION UNDER GRAVITY

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> % Assign the data (g, u, and t) to MATLAB variables % Calculate the value of s according to the formula % Plot the graph of s against t % Stop



VERTICAL MOTION UNDER GRAVITY

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This plan may seem trivial and a waste of time to write down. Yet you would be surprised how many beginners, preferring to rush straight to the computer, start with step 2 instead of step 1. It is well worth developing the mental discipline of structure-planning your program first. You can even use cut and paste to plan as follows:



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- **1** Type the structure plan into the Editor
- **2** Paste a second copy of the plan directly below the first.
- **3** Translate each line in the second copy into a MATLAB statement or statements
- Finally, paste all the translated MATLAB statements into the Command Window and run them
- 5 If necessary, go back to the Editor to make corrections



VERTICAL MOTION UNDER GRAVITY

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% Vertical motion under gravity $g = 9.81;$ % acceleration due
% to gravity
u = 60; % initial velocity in
% metres/sec
t = 0 : 0.1 : 12.3; % time in seconds
$s = u * t - g / 2 * t ^2; %$ vertical displacement
% in metres
<pre>plot(t, s), title('Vertical motion under gravity')</pre>
<pre>xlabel('time'), ylabel('vertical displacement')</pre>
grid
disp([t' s']) % display a table



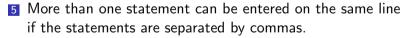
VERTICAL MOTION UNDER GRAVITY

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- **1** Anything in a line following the symbol % is ignored by MATLAB and may be used as a comment (description).
- **2** The statement t = 0: 0.1: 12.3 sets up a vector.
- **3** The formula for *s* is evaluated for every element of the vector t, making another vector.
- 4 The expression t.² squares each element in t. This is called an array operation and is different from squaring the vector itself.

VERTICAL MOTION UNDER GRAVITY

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- 6 A statement or group of statements can be continued to the next line with an ellipsis of three or more dots (\ldots) .
- **7** The statement disp([t' s']) first transposes the row vectors t and s into two columns and constructs a matrix from them, which is then displayed.



VERTICAL MOTION UNDER GRAVITY

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inan	Name \angle Value Min Max >> $g = 9.81;$	
	\blacksquare a $[1,2,-1;2,1,0]$ -1 2 \blacksquare $>>$ \parallel = 60.	
	\blacksquare ans [0.1270,0.91 0.1 0.9] $+ - 0 + 0 + 1 + 12 + 2$	
	B b [2,3,1;1,2,7] 1 7 >> t = 0 : 0.1 : 12.3; B balance 2.8099e+03 2.8 2.8 >> s = u * t − g / 2 * t .^2;	
	C <4x3 double> -1 7 ->> plot(t, s), title('Vertical motion under gravity')	
	g 9.8100 9.8 9.8 >> xlabel('time'), ylabel('vertical displacement')	
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	u = 60;	
	t = 0; t = 0 : 0.1 : 12.3;	
	s = u * t - g / 2 * t .^2;	
	plot(t, s), title('Vertical m	
	-xlabel('time'), ylabel('verti	
	grid	



VERTICAL MOTION UNDER GRAVITY

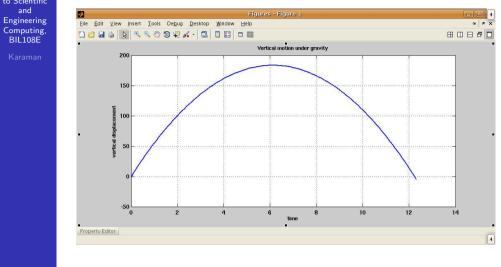
Introduction to Scientific and Engineering Computing, BIL108E

Δ			MATLAB 7.6.0 (R2008a)
<u>Eile Edit Deb</u>	ug <u>D</u> esktop <u>W</u> indow	Help	
1 6 8 1	1 9 C A 2 2	Current Dire	rectory: /home/sept/Desktop 👻 😢
Current Directory	Workspa	ce ++ 🗆 a :	× Command Window ↔ □ ₹
10 mi 10 lii (👌 🐻 🔤 🔹 Stack:	Base 👻	New to MATLAB? Watch this <u>Video</u> , see <u>Demos</u> , or read <u>Getting Started</u> .
Name ∠	Value	Min Max	>> q = 9.81;
a	[1,2,-1;2,1,0]	-1 2	>> u = 60;
🗄 ans	[0.1270,0.91		
H b	[2,3,1;1,2,7]	1 7	>> $t = 0 : 0.1 : 12.3;$
🗄 balance	2.8099e+03	2.8 2.8	>> s = u * t - g / 2 * t .^2;
H c	<4x3 double>	-1 7	<pre>- >> plot(t, s), title('Vertical motion under gravity')</pre>
∃g	9.8100	9.8 9.8	<pre>>> xlabel('time'), ylabel('vertical displacement')</pre>
Br	<49x49 dou	2.2 16	>> grid
🗄 rate	0.1200	0.1 0.1	
1	1 101 1		<pre> * >> disp([t' s']) </pre>
Command Histo	iru	(50+	0 0
			0.1000 5.9509
u = 60			0.2000 11.8038
t = 0	: 0.1 : 12.3;		0.3000 17.5586
s = u	*t-a/2*	t.^2:	0.4000 23.2152
	, s), title('	and the second se	
10 10 000 000		and the second second second	
xlabel	('time'), yla	bel (verti	
grid			0.7000 39.5966
	t' s'])		0.8000 44.8608
disp()			



VERTICAL MOTION UNDER GRAVITY

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References for Week 2

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- 2 Misza Kalechman, Practical Matlab Basics for Engineers, CRC Press, 2009.