MATLAB Basics

What is MATLAB?

MATLAB is a powerful tool for mathematical computations

It has extensive capabilities for generating graphs

It is used routinely by many engineers for solving modelling problems

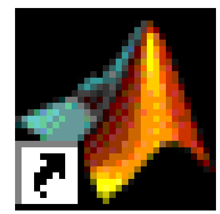
MATLAB can be used interactively or programs can be written for later execution

Error checking is very good – syntax errors are identified as code is written and there are very good diagnostic messages for program logic errors

Complete solutions to problems can be written very quickly

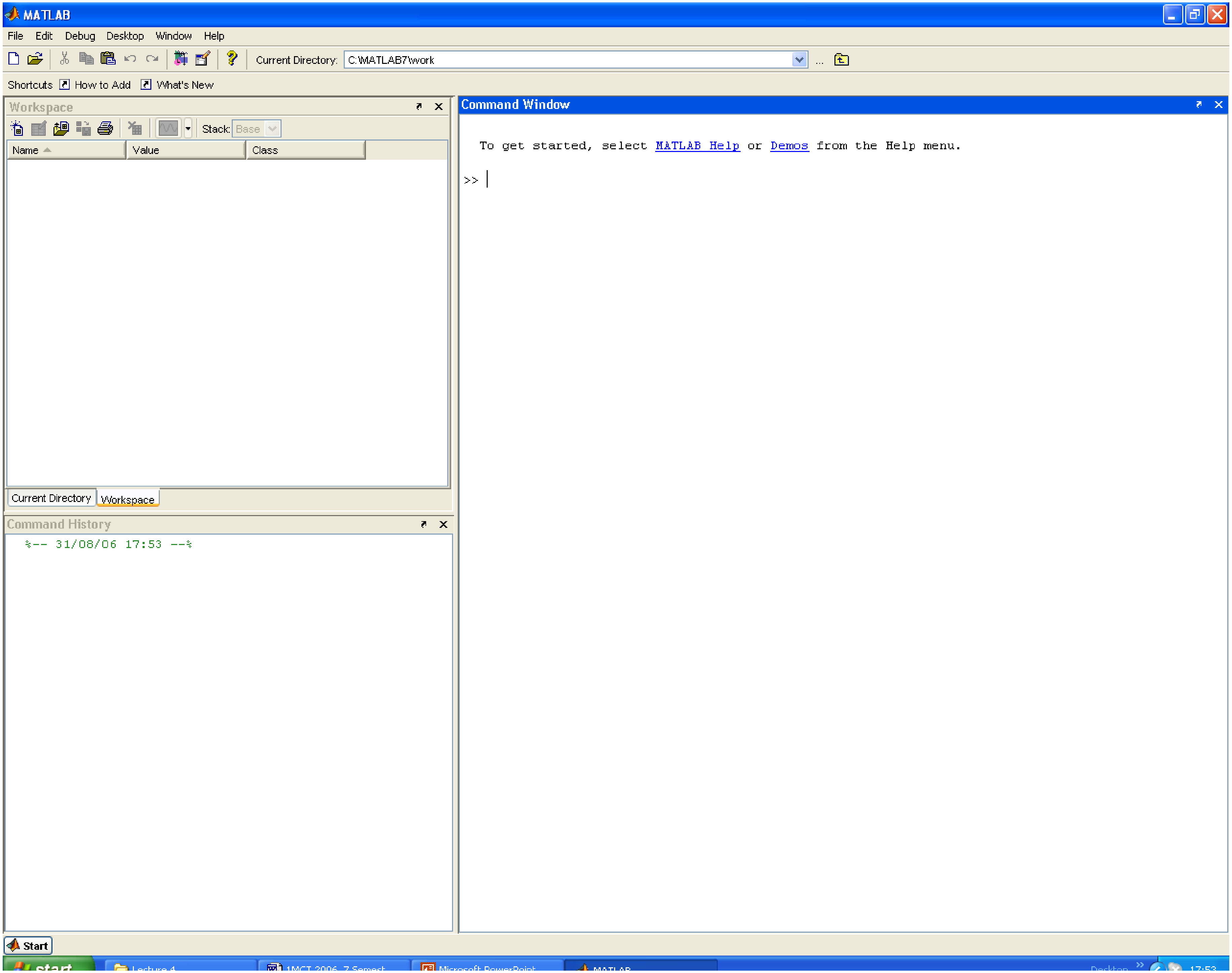
Starting MATLAB

In the clusters, you should find a shortcut on your desktop



MATLAB 7.0.lnk

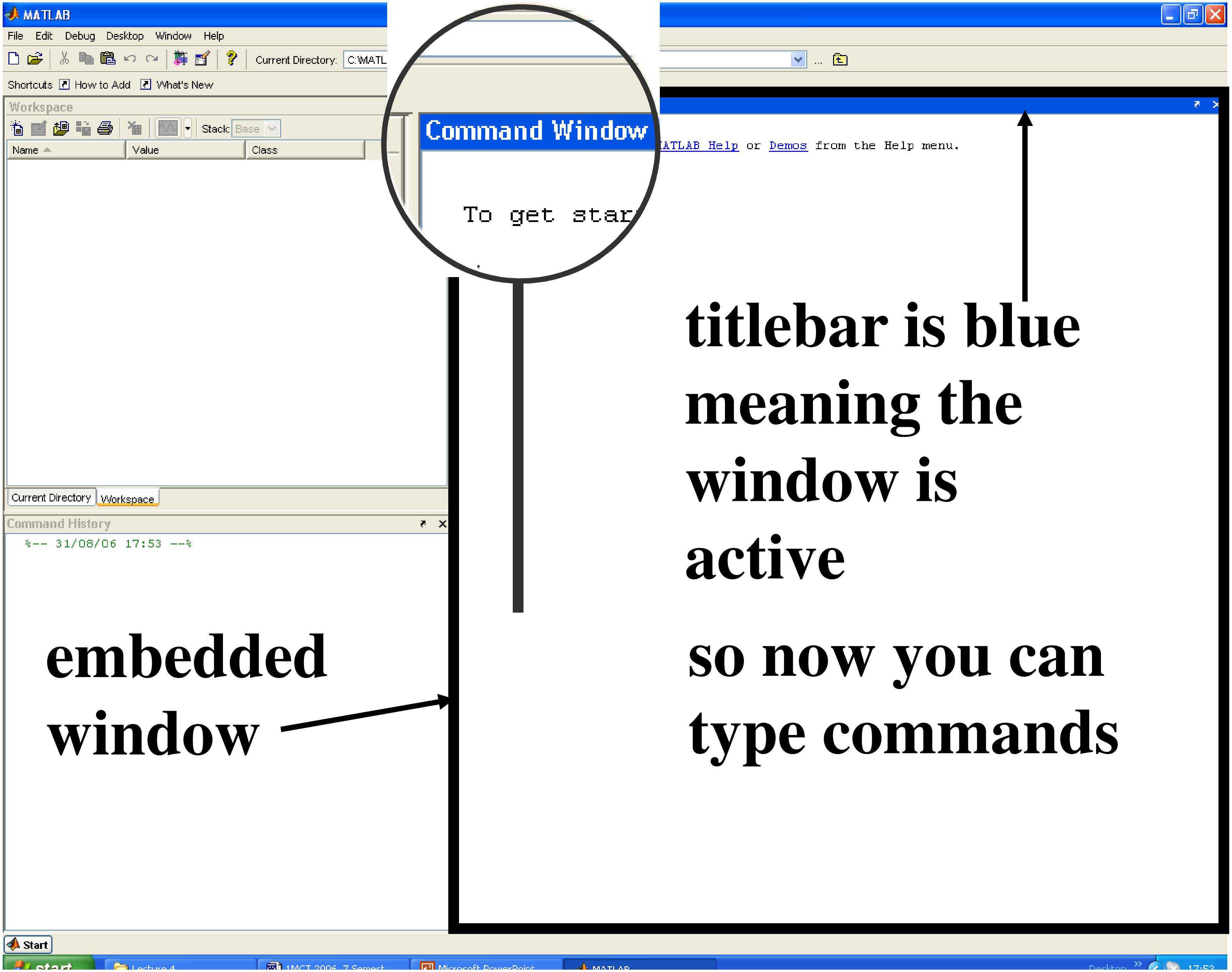
When MATLAB opens, you are presented with the MATLAB Desktop


MATLAB
File Edit Debug Desktop Window Help
Current Directory: C:\MATLAB7\work
Shortcuts How to Add What's New
Workspace
Stack: Base
Name Value Class
Current Directory Workspace
Command History
%-- 31/08/06 17:53 --%
Command Window
To get started, select MATLAB Help or Demos from the Help menu.
>>
Start

The Desktop should contain several embedded windows

of which the most important is the Command Window

This is where you can type commands i.e. instructions to the computer


MATLAB
File Edit Debug Desktop Window Help
Current Directory: C:\MATL
Shortcuts How to Add What's New
Workspace
Stack: Base
Name Value Class
Current Directory Workspace
Command History
%-- 31/08/06 17:53 --%
Command Window
To get star
ATLAB Help or Demos from the Help menu.
titlebar is blue meaning the window is active
so now you can type commands
embedded window
Start

type your command at the >> sign

NB: normally **extra spaces are ignored**

Command Window

```
  To get started, select MATLAB Help or Demos from the Help menu.

>> 2+2

ans =

     4

>> |
```

press Enter

and back comes the answer

There are lots of built in commands e.g.

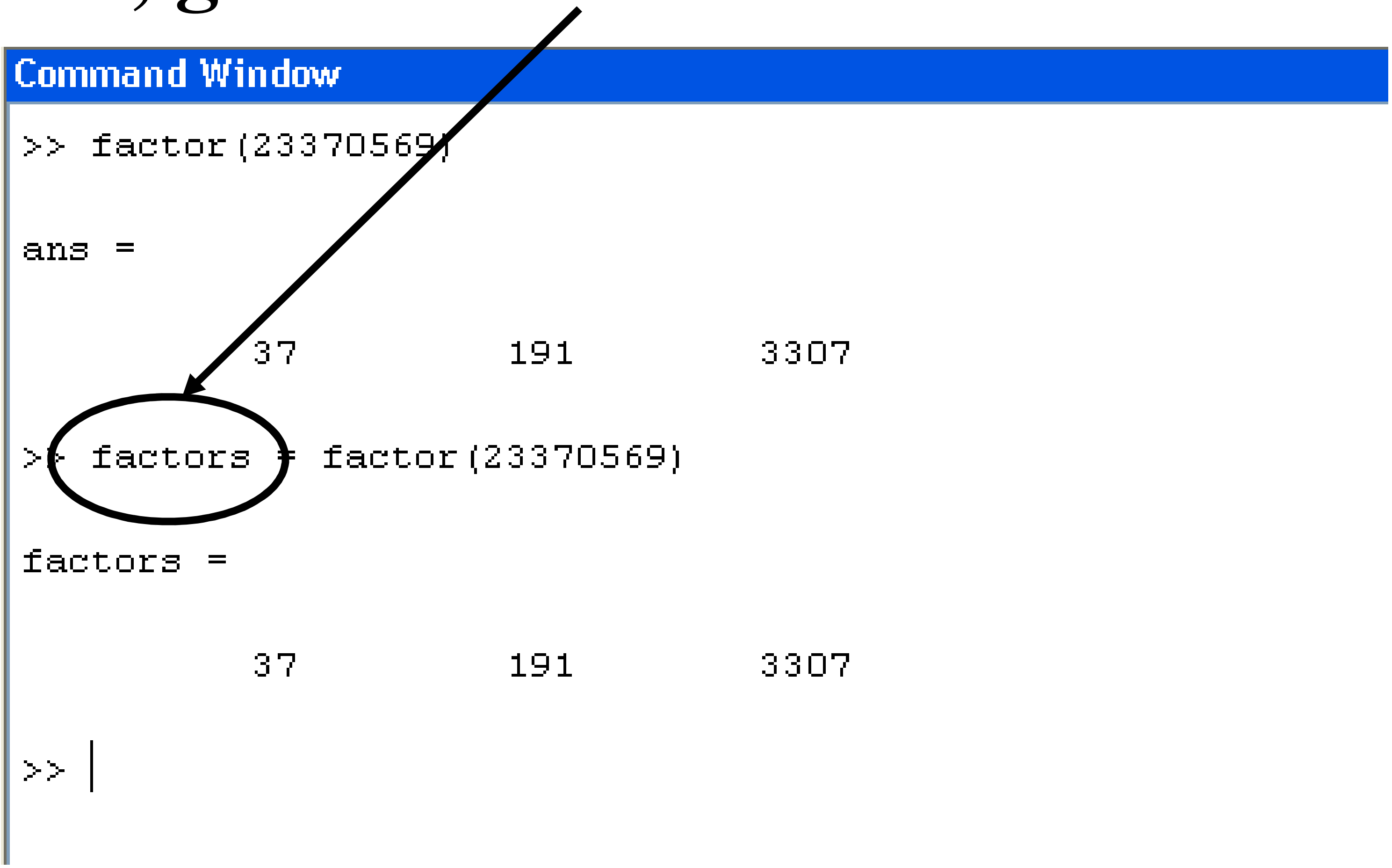
Command Window

```
>> factor(23370569)

ans =

        37         191        3307

>>
```

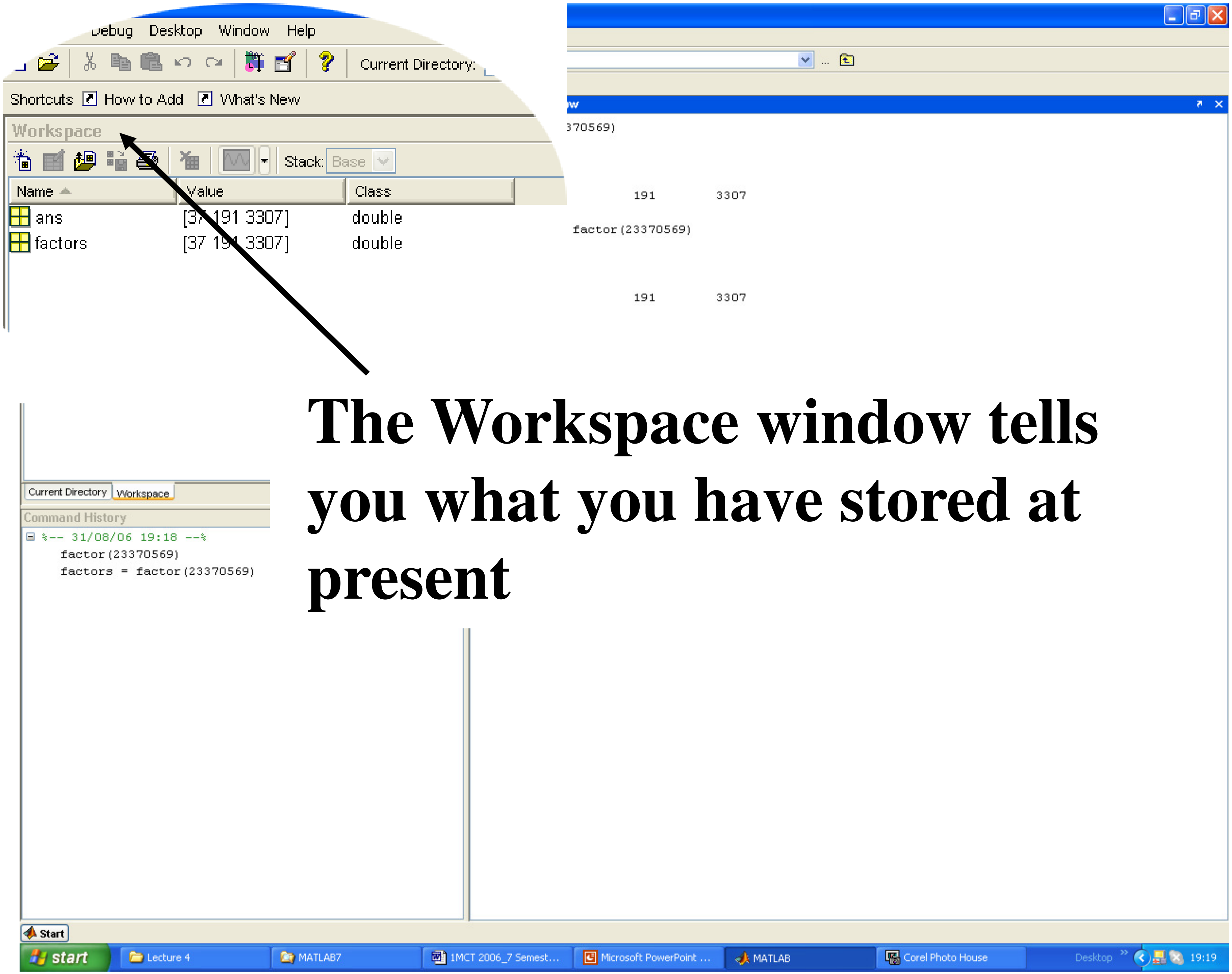
If you don't give your answer a name, it is called ans

MATLAB assigns a new answer to ans **with each calculation**

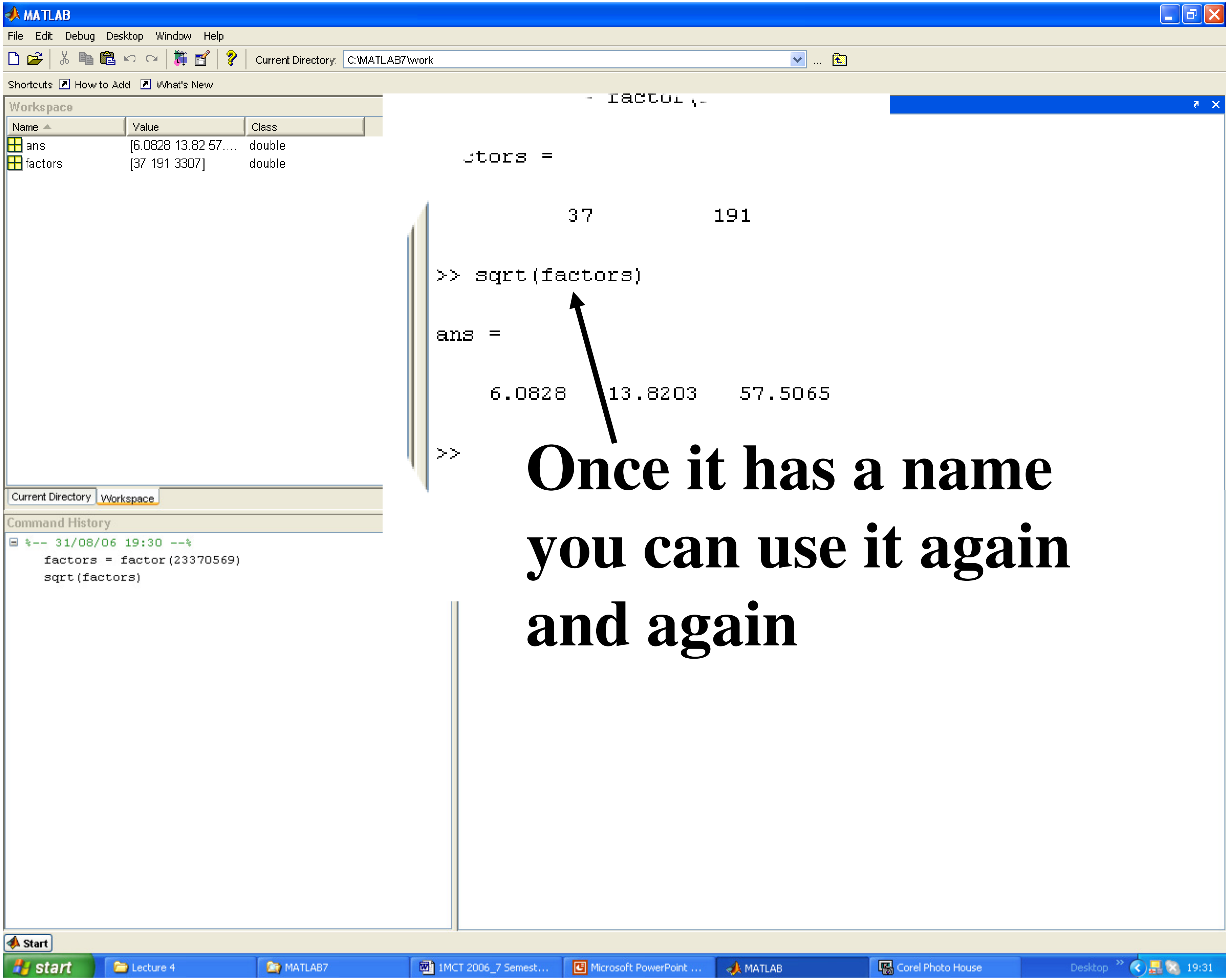
If you want to keep your answer for later, give it a name

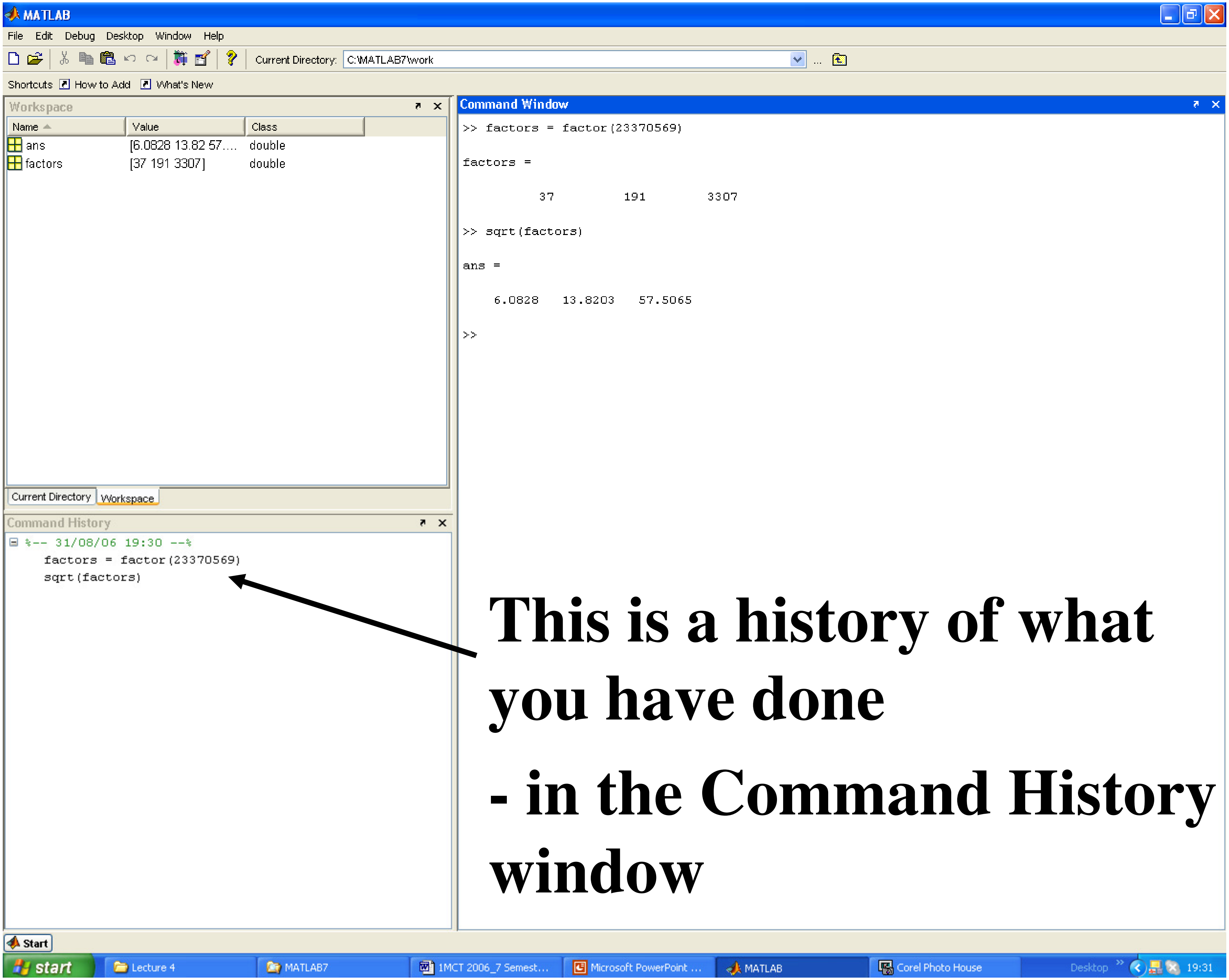


This is called assignment



The Workspace window tells you what you have stored at present

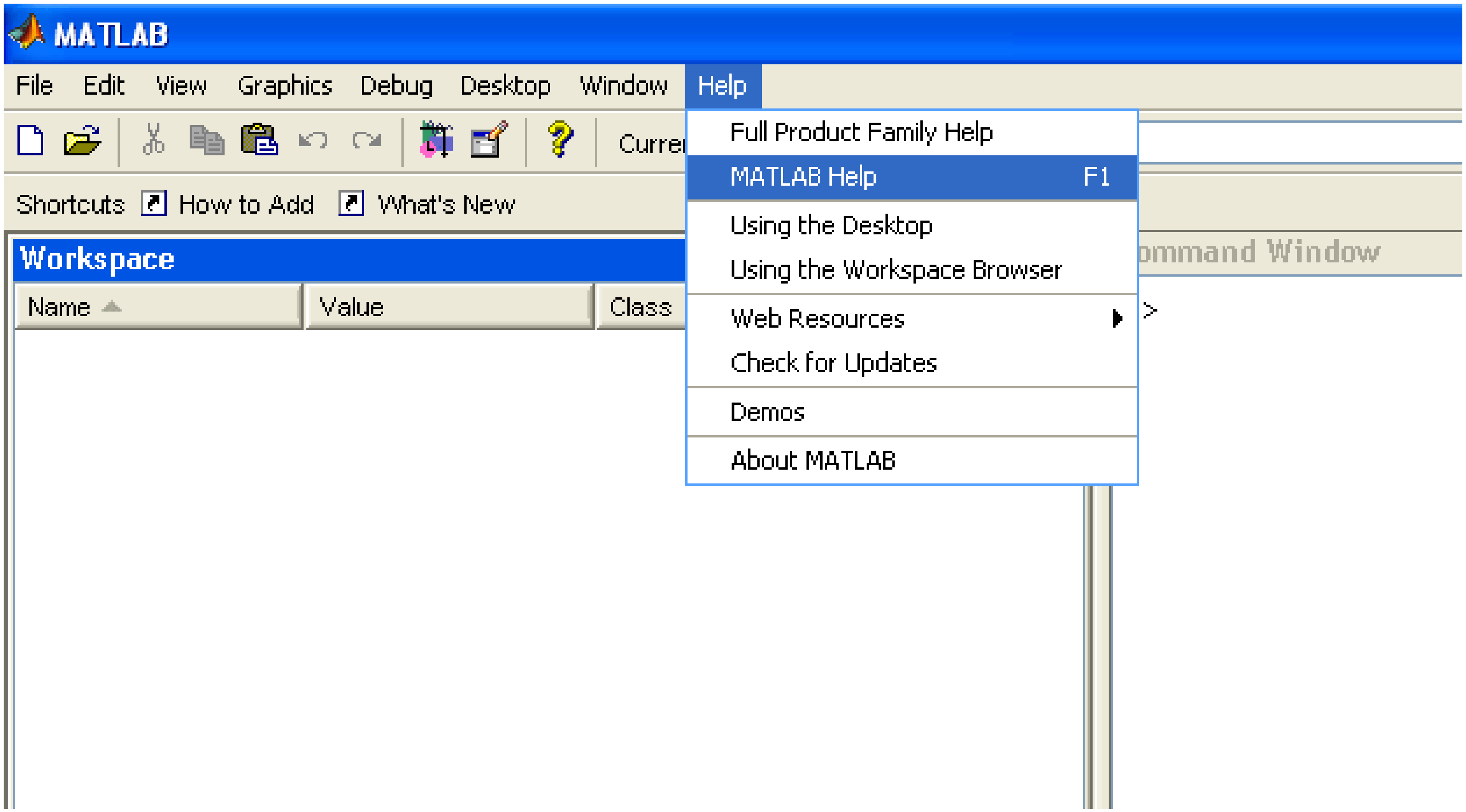

MATLAB
File Edit Debug Desktop Window Help
Current Directory: C:\MATLAB7\work
Shortcuts How to Add What's New
Workspace
Name Value Class
ans [6.0828 13.82 57.... double
factors [37 191 3307] double
Current Directory Workspace
Command History
%-- 31/08/06 19:30 --%
factors = factor(23370569)
sqrt(factors)
ctors =
37 191
>> sqrt(factors)
ans =
6.0828 13.8203 57.5065
>>
Once it has a name you can use it again and again
Start
start
Lecture 4
MATLAB7
1MCT 2006_7 Semest...
Microsoft PowerPoint ...
MATLAB
Corel Photo House
Desktop
19:31



This is a history of what you have done

- in the Command History window

There is lots of on-line help available



including video tutorials and demos

You can also get help on a particular command

Command Window

```
>> help factor
 FACTOR Prime factors.
    FACTOR(N) returns a vector containing the prime factors of N.

    This function uses the simple sieve approach. It may require large
    memory allocation if the number given is too big. Technically
    it is possible to improve this algorithm, allocating less
    memory for most cases and resulting in a faster execution
    time. However, it will still have problems in the worst
    case, so we choose to impose an upper bound on the input number
    and error out for n > 2^32.

    See also primes, isprime.

    Overloaded functions or methods (ones with the same name in other directories)
       help sym/factor.m

    Reference page in Help browser
       doc factor
```

Simple arithmetic

- just like a calculator!

+	add
–	subtract
*	multiply
/	divide
^	exponentiate (power)

Use brackets as necessary

>> 3^2 – (1 + 3)/2 + 5*2

Pressing Enter gives

```
>> 3^2 – (1 + 3)/2 + 5*2

ans =

    17
```

Making and fixing errors

If you make a syntax error in typing your command

MATLAB will print an error message

```
>> 2a
??? 2a
     |
Error: Missing MATLAB operator.
```

>> 2*a would be correct

Semicolon

In MATLAB, one use of a semicolon (;) is to suppress output to the screen (Command Window) e.g.

```
>> x = 3
x =

    3
```

(the lines "x =" and "3" are the output to screen)

but

>> x = 3; **gives no output** to the screen

Note the result will still be stored in the Workspace for later use

This use of the semicolon is common when writing programs, or if one is generating a large variable at the command line (see later)

Digression: scalars, vectors, arrays and matrices

A scalar quantity is one that is defined by a single number – its size or magnitude (with appropriate units)

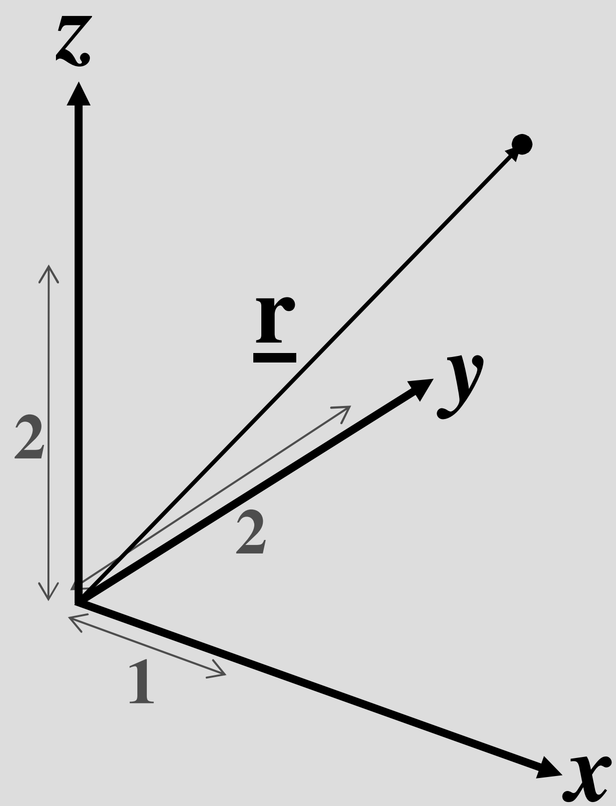
Example: a speed of 100 km h^{-1}

A vector has magnitude and direction

Example:
a velocity of 100 km h^{-1} due South

If you think about direction in coordinates, you will realise that a vector can also be considered an ordered list of numbers e.g.

the direction is 1 unit along the *x* axis, 2 units along the *y* axis, and 2 unit along the *z* axis



As long as we know what our base directions are (*x*, *y* and *z*)

we could describe the vector r

as r = [1, 2, 2]

Arrays

An array is a collection of objects (elements), of identical type, in a rectangular arrangement

An array of ?

Matrices

A matrix is an array of numbers e.g.

$$\begin{pmatrix} -1 & 0 & 0 \\ 1 & 1 & 0 \\ 0 & -1 & 1 \end{pmatrix}$$

… although not all arrays of numbers are matrices

MATLAB stands for MATrix **LAB**oratory

A vector can be thought of as a matrix with only one row or one column

$$\begin{pmatrix} -1 & 0 & 0 \end{pmatrix} \qquad \begin{pmatrix} -1 \\ 1 \\ 0 \end{pmatrix}$$

and a scalar as a matrix with only one " element "

$$\begin{pmatrix} -1 \end{pmatrix}$$

Assignment Statements

x = 4 **(x *is a scalar*)**

Note that " = " in MATLAB is an *assignment* operator

It is therefore perfectly OK to write

```
>> x = x + 1
```

See A VERY, VERY, Brief Guide to MATLAB for a summary of MATLAB syntax

x = x + 1 would be incorrect in normal algebra but here means:

the (new) value of x becomes the (previous) value of x plus 1

or, more simply:

x becomes x plus 1

More Assignment Statements

y = [2, 3] **y** ***is a row vector***
i.e a matrix with only 1 row

Creating a matrix:

A = [-1, 0, 0; 1, 1, 0; 0, -1, 1]

A ***is a 3x3 matrix***

$$\underline{A} = \begin{pmatrix} -1 & 0 & 0 \\ 1 & 1 & 0 \\ 0 & -1 & 1 \end{pmatrix}$$

Looking at the syntax more closely:

A = [-1, 0, 0; 1, 1, 0; 0, -1, 1]

a "," is a divider, separating elements on a row

the ";" here separates rows i.e. starts a new row

(NB: a second use of ";")

You can also use a space as an element divider e.g. A = [-1 0 0; 1 1 0; 0 -1 1] which gives the same A as above

$$\underline{C} = \begin{pmatrix} 1 & 2 \\ 3 & 6 \\ 2 & 5 \end{pmatrix}$$

This is a rectangular matrix with 3 rows and 2 columns

Its size is 3x2

In MATLAB: C = [1 3; 3 6; 2 5]

size(C) is a MATLAB function that outputs the number of rows in nr and the number of columns in nc – can be very useful in handling matrices

Use it like >> [nr nc] = size(C)

A = [1, 2, 3; 4, 5, 6; 7, 8, 9]

b = A(3, 2) sets b to the element that is in the third row, second column of A

This is 8 in this case

You can also use this to assign values to elements e.g. A(3, 2) = 0 giving

A = [1, 2, 3; 4, 5, 6; 7, 0, 9]

The difference is that in the second case **A(3, 2)** is on the left hand side of " **=** "

Digression: Matrix addition and subtraction

Matrix addition and subtraction behave as as you might expect, as does multiplication by a scalar

$$A = \begin{pmatrix} 2 & 3 \\ 1 & 7 \end{pmatrix} \quad B = \begin{pmatrix} 3 & 3 \\ 0 & 1 \end{pmatrix}$$

$$\text{then } A + B = \begin{pmatrix} 2+3 & 3+3 \\ 1+0 & 7+1 \end{pmatrix} = \begin{pmatrix} 5 & 6 \\ 1 & 8 \end{pmatrix}$$

Matrix multiplication

does not work as you might expect

This is NOT how it is done:

$$A = \begin{pmatrix} 2 & 3 \\ 1 & 7 \end{pmatrix} \quad B = \begin{pmatrix} 3 & 3 \\ 0 & 1 \end{pmatrix}$$

$$\text{then } A * B \neq \begin{pmatrix} 2\times3 & 3\times3 \\ 1\times0 & 7\times1 \end{pmatrix}$$

Do not try to do this!

Matrix multiplication is row $\times$ column

Each element of a row is multiplied by the corresponding element in a column, and the results are added to give one element of the new matrix

This is located where the row and column intersect

Hard to describe, easy to do ....

$$A = \begin{pmatrix} 2 & 3 \\ 1 & 7 \end{pmatrix} \quad B = \begin{pmatrix} 3 & 3 \\ 0 & 1 \end{pmatrix}$$

$$\text{then } A * B = \begin{pmatrix} (2\times3)+(3\times0) & (2\times3)+(3\times1) \\ (1\times3)+(7\times0) & (1\times3)+(7\times1) \end{pmatrix}$$

$$\text{Similarly, if } A = \begin{pmatrix} 1 & 3 & 2 \\ 1 & 2 & 4 \end{pmatrix} \text{ and } B = \begin{pmatrix} 3 & 4 \\ 1 & 0 \\ 0 & 1 \end{pmatrix}$$

$$\text{then } A * B = ?$$

$$A * B = \begin{pmatrix} 6 & 6 \\ 5 & 8 \end{pmatrix}$$

NB: we can only multiply matrices if the number of columns of the first matrix equals the number of rows of the second

For example, we cannot evaluate

$$A * B \text{ if } A = \begin{pmatrix} 1 & 3 & 2 \\ 1 & 2 & 4 \end{pmatrix} \text{ and } B = \begin{pmatrix} 3 & 4 \\ 1 & 0 \end{pmatrix}$$

If A is a $n \times m$ matrix, and B is a $p \times q$ matrix, A * B only exists if $m = p$

If $m = p$, then the resulting matrix has dimensions $n \times q$

$$\boldsymbol{n \times \cancel{m, m} \times q \longrightarrow n \times q}$$

Remember from earlier:

$$A = \begin{pmatrix} 1 & 3 & 2 \\ 1 & 2 & 4 \end{pmatrix} \text{ and } B = \begin{pmatrix} 3 & 4 \\ 1 & 0 \\ 0 & 1 \end{pmatrix} \text{ then } A * B = \begin{pmatrix} 6 & 6 \\ 5 & 8 \end{pmatrix}$$

$$\boldsymbol{2 \times \cancel{3} \qquad \cancel{3} \times 2 \longrightarrow 2 \times 2}$$

A = [1, 2, 3; 4, 5, 6; 7, 8, 9]

B = [1 0 1; 0 1 0; 1 1 0]

A*B in MATLAB is matrix multiplication

In this case
A*B = [4, 5, 1; 10, 11, 4; 16, 17, 7]

Note that in general A*B ≠ B*A, and A*B = 0 does not imply either A or B is necessarily 0

A.*B in MATLAB is multiplication element by element

$$\underline{A}.*\underline{B} = \begin{pmatrix} 1 & 0 & 3 \\ 0 & 4 & 0 \\ 7 & 8 & 0 \end{pmatrix}$$

Similarly A.^2 means square each element of A, but A^2 equals A*A

A = A' transposes A

Transpose means swap rows and columns

$$\underline{A} = \begin{pmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 0 & 9 \end{pmatrix} \qquad \underline{A}' = \begin{pmatrix} 1 & 4 & 7 \\ 2 & 5 & 0 \\ 3 & 6 & 9 \end{pmatrix}$$

If A = [1 2 3; 4 5 6; 7 0 9] then
A' = [1 4 7; 2 5 0; 3 6 9]

If y = [2, 3], then y' = [2; 3]

A = inv(A) gives the inverse of the matrix

inv(A)*A = I
where I is the "identity matrix"

The identity matrix behaves like the number 1 in arithmetic but might look like

$$\underline{I} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

The size is variable and here would be the same as A

To find the inverse A has to be "square" i.e. the same number of rows as columns

Also its determinant must not equal zero

Say A*x = b **, then**

inv(A)*A*x = I*x = x = inv(A)*b

This could be used to solve systems of linear equations (for x **here), but it is usually more efficient for a computer to do Gaussian elimination**

A\b is matrix division in MATLAB , used for solving sets of linear equations by Gaussian elimination

Say $\underline{A}\ \underline{x} = \underline{b}$

Then in MATLAB: x = A\b

e.g.
```
>> A = [1 1;1 4]
>> b = [1; 2.5]
>> A\b gives [0.500
             0.500]
```

Colon Operator

If a colon is used to separate two integers, it generates all the integers between them e.g.

>> c = 1:8

***creates a vector* c =**

The step size can be defined e.g.

>> b = 0:2:8

***creates a vector* b = [0 2 4 6 8]**

The step size can be negative for a countdown e.g.

>> d = 2:- 0.2:1

creates a vector **d** *containing numbers dropping in steps of 0.2 from 2 to 1 inclusive*

d = ?

Concatenation

Concatenation means creating larger matrices from smaller ones - not addition e.g. if

A = [1 1;1 4] and B = [1 2; 3 0]
Then C = [A B] gives C = [1 1 1 2; 1 4 3 0]

$$\underline{C} = \begin{pmatrix} 1 & 1 & 1 & 2 \\ 1 & 4 & 3 & 0 \end{pmatrix}$$

$\underline{A}$ $\underline{B}$

On the other hand, with the same A = [1 1;1 4] and B = [1 2; 3 0]

C = [A; B] gives C = [1 1; 1 4; 1 2; 3 0]

row separator

$$\underline{C} = \begin{pmatrix} 1 & 1 \\ 1 & 4 \\ 1 & 2 \\ 3 & 0 \end{pmatrix} \begin{matrix} \underline{A} \\ \\ \underline{B} \end{matrix}$$

Special constants and values are often available in MATLAB

e.g. **pi** *represents* π

Inf *infinity*

NaN *not a number*

Strings

MATLAB can handle strings i.e. bits of text

It does this by treating text as a matrix of characters

Use single quotes to show you are dealing with text e.g.

```
>> message = 'Hello world'
```

You can use concatenation to built more complex text e.g.
>> big_message = [message; 'from Fred']

You can display your text on the screen using the function disp
>> disp(big_message)

There are many ways to control screen output e.g. fprintf

MATLAB Functions

As in Excel, MATLAB provides lots of built-in **functions for you to use**

e.g. sqrt, exp, log, sin, cosh ….

```
>> y=[1 2 3 4 5];
>> z=sqrt(y)
z =
   1.0000    1.4142    1.7321    2.0000    2.2361
```

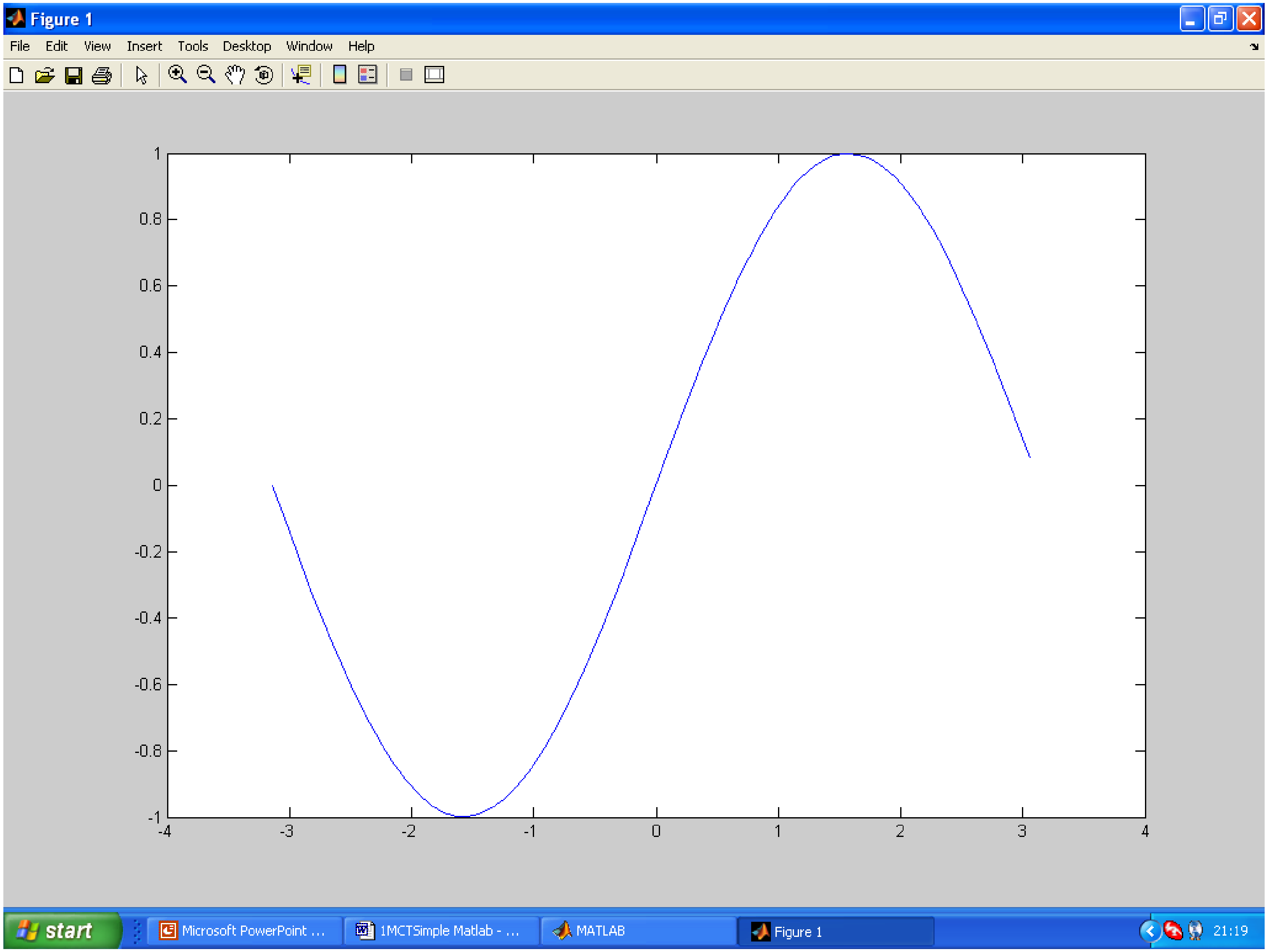
This is "vectorisation" is one reason for the power of MATLAB

Plots

plot(x,y) produces a graph of y against x, where x and y are vectors

plot takes in data sets and outputs a plot or "figure"

e.g.
```
>> x = -pi:0.1:pi;
>> y = sin(x);
>> plot(x,y)
```



There are many ways to improve the look of your plots!

Digression: Computer representation of numbers

Decimal: 123.45 means

$$1 \times 10^2 + 2 \times 10^1 + 3 \times 10^0 + 4 \times 10^{-1} + 5 \times 10^{-2}$$

Using scientific notation, this is written as 1.2345×10^2

Computers use an adaptation of scientific notation called "floating point" representation

For example, in MATLAB:

123.45 becomes

1.2345e+002 **e+002 means 10^2**

Of course, internally computers work in binary i.e. powers of 2, not 10

Computers represent numbers as a string of bits e.g. 53 binary digits

Only some (decimal) numbers can be represented *exactly* in a computer

The true mathematical result of a calculation might not be one of these

In common "double precision" representation, consecutive numbers differ by about 1 part in 10^{16}

This can result in numerical errors e.g.

```
>> 1 - 0.2 - 0.2 - 0.2 - 0.2 - 0.2

ans =

   5.5511e-017
```

```
>> sin(pi)

ans =

   1.2246e-016
```

Most of the time, such errors in numerical calculations in MATLAB will be unimportant

Matlab Script Files

Although a lot can be done from the command line, it is often useful to write a MATLAB program or “script”

A script is stored in a text file, with the extension .m - hence “m-files”

When you invoke a script by typing its name in the command line, it simply executes the commands in the file

Example: simplified version of **magicrank.m from the "Getting Started" tutorial**

magic(n) makes a magic square of size n

```
% investigate the rank of magic squares
for n = 3:32
        r(n) = rank(magic(n));
end
bar(r)
```

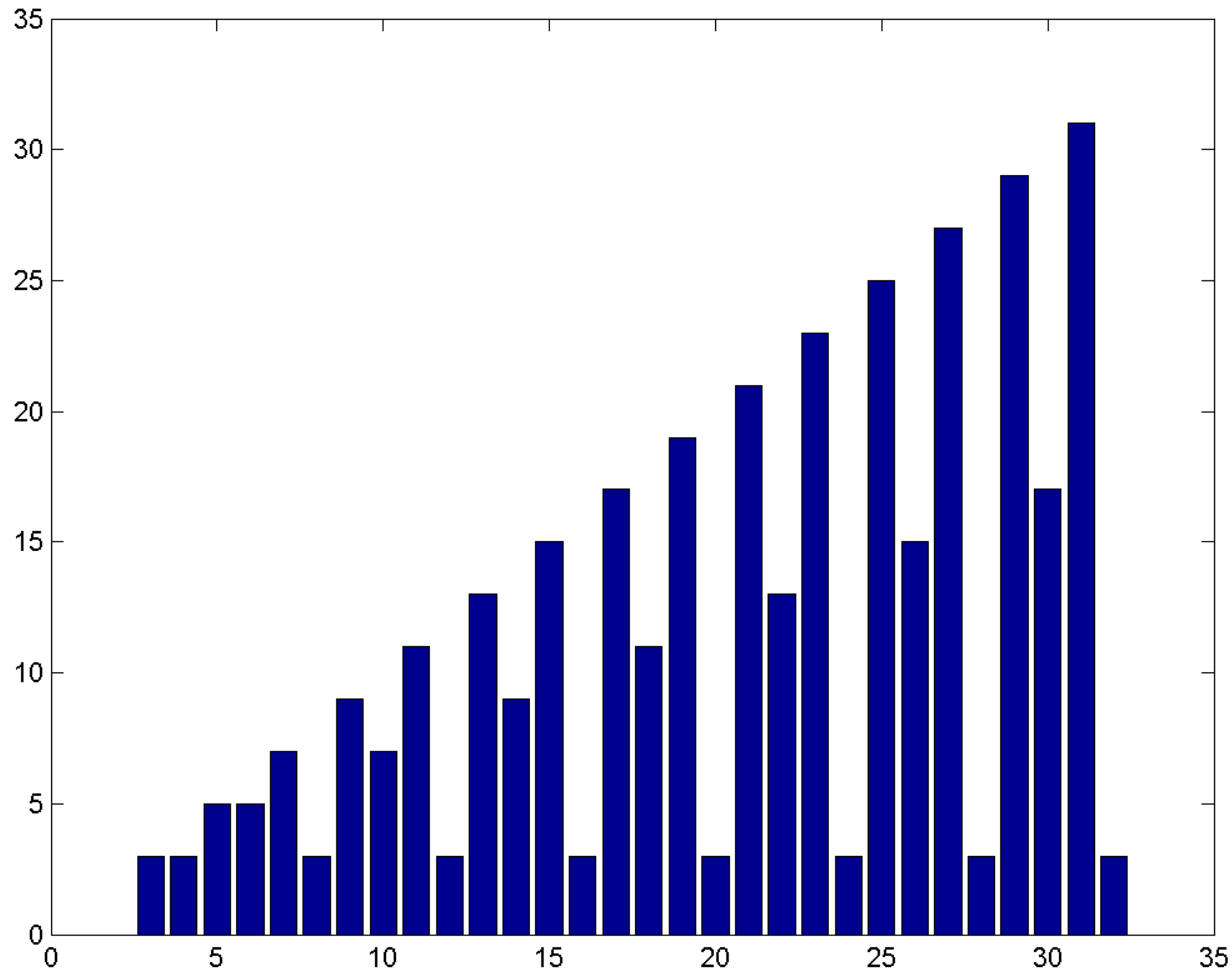
Loops through values of n from 3 to 32 making magic squares

and storing the rank in a vector r

bar chart of ranks

comment ignored by the program

>> magicrank ⟵ at command line



For simple problems, the command line is fast and efficient

For larger problems, or if you wish to change variable values, or have loops or branches, or modify the commands, use script files

Note that you can store your script files and reuse them in other work

Useful functions for script files:

disp(ans)	**Displays results without identifying variable names**
echo	**Turning echo on displays the script commands as they are executed - good for "debugging"**
input	**Prompts user for input**
pause	**Pause until user presses any keyboard key**
pause(n)	**Pause for n seconds**
waitforbuttonpress	**Pause until user presses mouse button or keyboard key**

If you ever need to stop execution of a command or script file, press Ctrl-C i.e. the Control and C keys simultaneously e.g.

```
for p = 1:1000
for q = 1:1000
A(p,q) = p*q
end
end
```

"for" loops are discussed later

A better approach might be

```
A = zeros(1000,1000);
for p = 1:1000
        for q = 1:1000
                A(p,q) = p*q;
        end
end
```

puts room aside in memory for your matrix, by making a matrix of 0's – handy trick to speed things up

; to suppress output

Polynomials in MATLAB

In MATLAB, polynomials are represented by a row vector of the coefficients

e.g. a polynomial $f = 3x^3 - x^2 - 1$ is specified by the coefficient vector
$a = [3 \;\; -1 \;\; 0 \;\; -1]$

Polynomial Functions

See the VERY, VERY Brief Guide to MATLAB for the polynomial functions

polyval(a, x) : to evaluate a polynomial with coefficient matrix a at x

$f = 3x^3 - x^2 - 1$

```
>> a = [3  –1  0  –1]
>> polyval(a, 1)
ans =
        1
```

Polynomial Functions

roots(a) : to find the roots of a polynomial

poly(r) : to find the coefficient matrix from the roots

$f = 3x^3 - x^2 - 1$

```
>> a = [3  –1  0  –1]

>> r = roots(a)

r =
   0.8241
  -0.2454 + 0.5867i
  -0.2454 - 0.5867i
```

$f = 3x^3 - x^2 - 1$

```
>> r =
   0.8241
  -0.2454 + 0.5867i
  -0.2454 - 0.5867i
>> poly(r)

ans =

    1.0000   -0.3333   -0.0000   -0.3333
```

Polynomials and Regression

p = polyfit(x, y, n)

order of fitted polynomial

vector of x values

vector of corresponding y values

coefficients of polynomial that fits data best on least square basis

Flow Control

If you want to loop e.g. do something lots of times, with a different value of a variable each time
or if you want your program to make decisions while it is running, you need

"flow control"

MATLAB has five “constructs” for flow control

- if
- switch
- for
- while
- break

if

```
if      <logical condition>
        <statements for first case>
elseif <logical condition>
        <statements for second case >
else
        <otherwise>
end
```

if

```
if      mark >= 69.5
        firstclass
elseif mark >= 40
        pass
else
        fail
end
```

If if finds a condition is satisfied, it executes the statement(s) that follow immediately, and then goes to end

Notes only:

switch

```
switch <variable or expression>
    case  <some value(s)>
        <statements for first case(s)>
    case  <some value(s)>
        <statements for second case(s)>
    case  <some value(s)>
        <statements for third case(s)>
    otherwise
        <statements for other case(s)>
end
```

Notes only:

switch

```
switch lower(input('What day is it? ', 's'))
    case {‘saturday', ‘sunday'}
        disp('Weekend - hurrah!')
    case {‘monday',‘friday'}
        disp('More weekend - cool')
    case {‘tuesday', ‘wednesday', …
                                  'thursday'}
        disp('Rest day - wicked')
    otherwise
        disp('Not a day')
end
```

NB “ …” is means continue the line below

Notes only:

switch works down the cases

When it finds a true condition, it executes the statement(s) that follow immediately, then goes to end

for

```
for n = 3:32
        r(n) = rank(magic(n));
end
```

Executes the statements the stated number of times

Note: you can have steps other than 1

e.g. n = 2:2:100 - even numbers up to 100

n = 10:-1:0 - countdown

while

Repeats statements until some logical condition is met

```
n = 1;
while n <= 500
    disp(n)
    n = n^2+ 1;
end
```

Note the use of indenting in loops – helps make the code much easier to read

break

Useful if you need to exit early from a loop

```
n = 1;
while n <= 5000
    disp(n)
    n = n^2+ 1;
    if n == 26 break
    end % if
end
```

MATLAB Functions

Functions are m-files that can accept input "arguments" and return "output arguments"

The function m-file "blanks.m" is a simple example

>>type blanks

gives the contents of the file blanks.m

```
function b = blanks(n)
%BLANKS String of blanks.
%   BLANKS(n) is a string of n blanks.
%   Use with DISP, eg.  DISP(['xxx' BLANKS(20) 'yyy']).
%   DISP(BLANKS(n)') moves the cursor down n lines.
%
%   See also CLC, HOME, FORMAT.

%   Copyright 1984-2002 The MathWorks, Inc.
%   $Revision: 5.10 $  $Date: 2002/04/15 03:53:35 $

space = ' ';
b = space(ones(1,n));
```

```
function b = blanks(n)
```

The first line starts with the word function
It gives the function name, and the order of the "arguments"

Here there is only one input: n
This is the number of blanks required

There is one output b, a string of n blanks

```
function b = blanks(n)
%BLANKS String of blanks.
%   BLANKS(n) is a string of n blanks.
%   Use with DISP, eg.  DISP(['xxx' BLANKS(20) 'yyy']).
%   DISP(BLANKS(n)') moves the cursor down n lines.
%
%   See also CLC, HOME, FORMAT.
```

The comment lines that follow are the help text you see when you type

```
>> help blanks
```

If you write your own, this will work for your functions too!

The rest of the code is what the function does

```
space = ' ';
b = space(ones(1,n));
```

Note that one line, often the last, gives a value for the output, here b

You can “call” the function from the command line or from another m-file

```
>> myblanks = blanks(6)
myblanks =

>> xxblanks = ['x' blanks(6) 'x']
xxblanks =
x      x
```

Note the concatenation here

```
>> myblanks = blanks(6)
```

```
function b = blanks(n)
%BLANKS String of blanks.
%   BLANKS(n) is a string of n blanks.
%   Use with DISP, eg.  DISP(['xxx' BLANKS(20) 'yyy']).
%   DISP(BLANKS(n)') moves the cursor down n lines.
%
%   See also CLC, HOME, FORMAT.

%   Copyright 1984-2002 The MathWorks, Inc.
%   $Revision: 5.10 $  $Date: 2002/04/15 03:53:35 $

space = ' ';
b = space(ones(1,n));
```

Note that everything inside a function is hidden from the outside

If we call blanks from the command line, the value of b and n are not defined (known) outside the function

```
>> blanks(6)
ans =

>> b
??? Undefined function or variable 'b'.
```

This means we don’t have to worry about the function altering the values of variables we have defined

```
>> b=6;
>> blanks(6)
ans =

>> b
b =
    6
```

not 6 blanks!

If we want to share a variable between the inside of a function and outside, we might declare the variable as "global"

However, it is better practice to pass all variables in and out as arguments

User-defined functions

MATLAB has lots of functions to play with, but you may want to write your own – as a function m-file.

For example, you may want a function which changes £ into $

```
function dollars = convert(pounds)
%CONVERT changes a given amount of
%pounds sterling into US dollars, using a global value
%for the exchange rate.  It rounds down to a whole
%number of dollars.

global exchange_rate
dollars = floor(exchange_rate*pounds);
```

This is stored on the path as an m-file called convert.m

It can then be called from the command line or another m-file

For example

```
>> global exchange_rate
>> exchange_rate = 1.5;
>> pounds = 200;
>> mydollars = convert(pounds)

mydollars =

      300
```

An advantage of such files is that you can re-use them

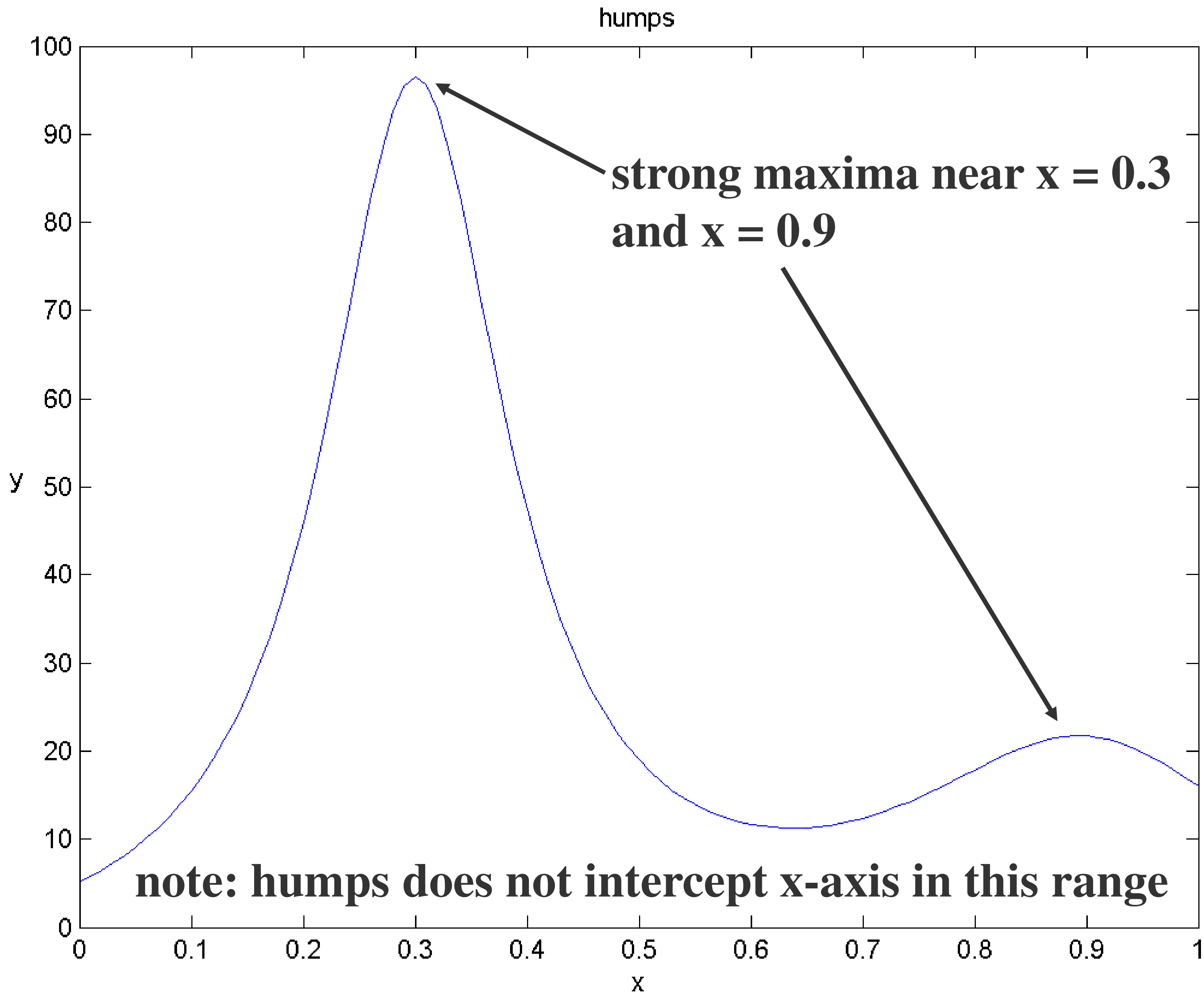
Simple Numerical Analysis in MATLAB

“Function functions” are functions that have other functions as inputs

Examples are finding minima, finding roots, quadrature, and solving ODEs numerically

MATLAB's favourite function is humps; a curve generated by the equation

$$y = \frac{1}{(x-0.3)^2 + 0.01} + \frac{1}{(x-0.9)^2 + 0.04} - 6$$



humps
strong maxima near x = 0.3
and x = 0.9
note: humps does not intercept x-axis in this range
y
x
0
10
20
30
40
50
60
70
80
90
100
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

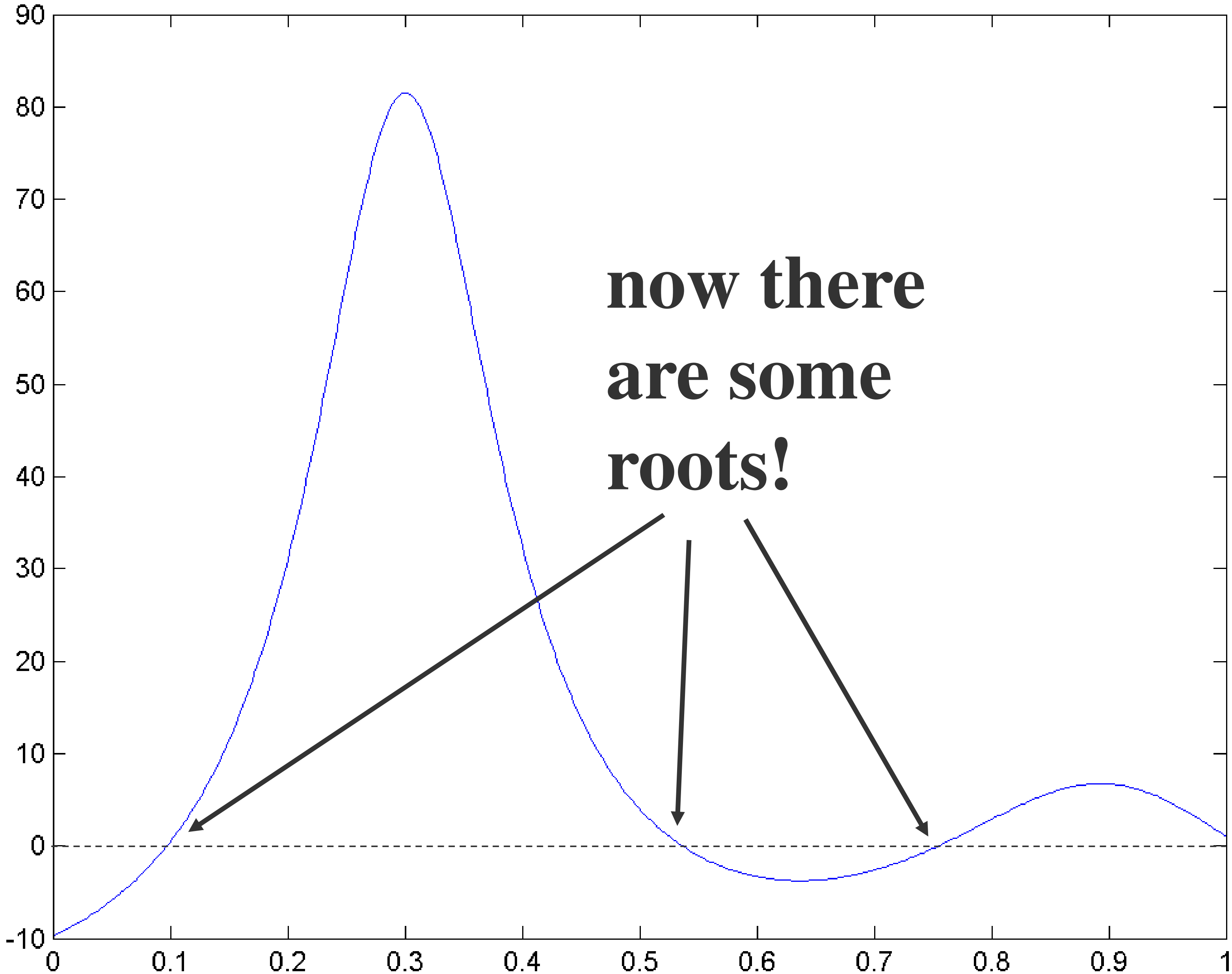
MATLAB's favourite function is humps
Here is a modified version: newhumps

```
function y = newhumps(x)
%NEWHUMPS  A modified simple version of MATLAB's humps.
%   Y = HUMPS(X) is a function with strong maxima near x = .3
%   and x = .9.
%   Y =NEWHUMPS(X) subtracts 15 from HUMPS to ensure
%   some roots in the range 0 <= x <= 1.

y = (1 ./ ((x-.3).^2 + .01) + 1 ./ ((x-.9).^2 + .04) - 6) -15;
```

If we try

```
>> x = 0:0.002:1;
>> y = newhumps(x);
>> plot(x,y)
```

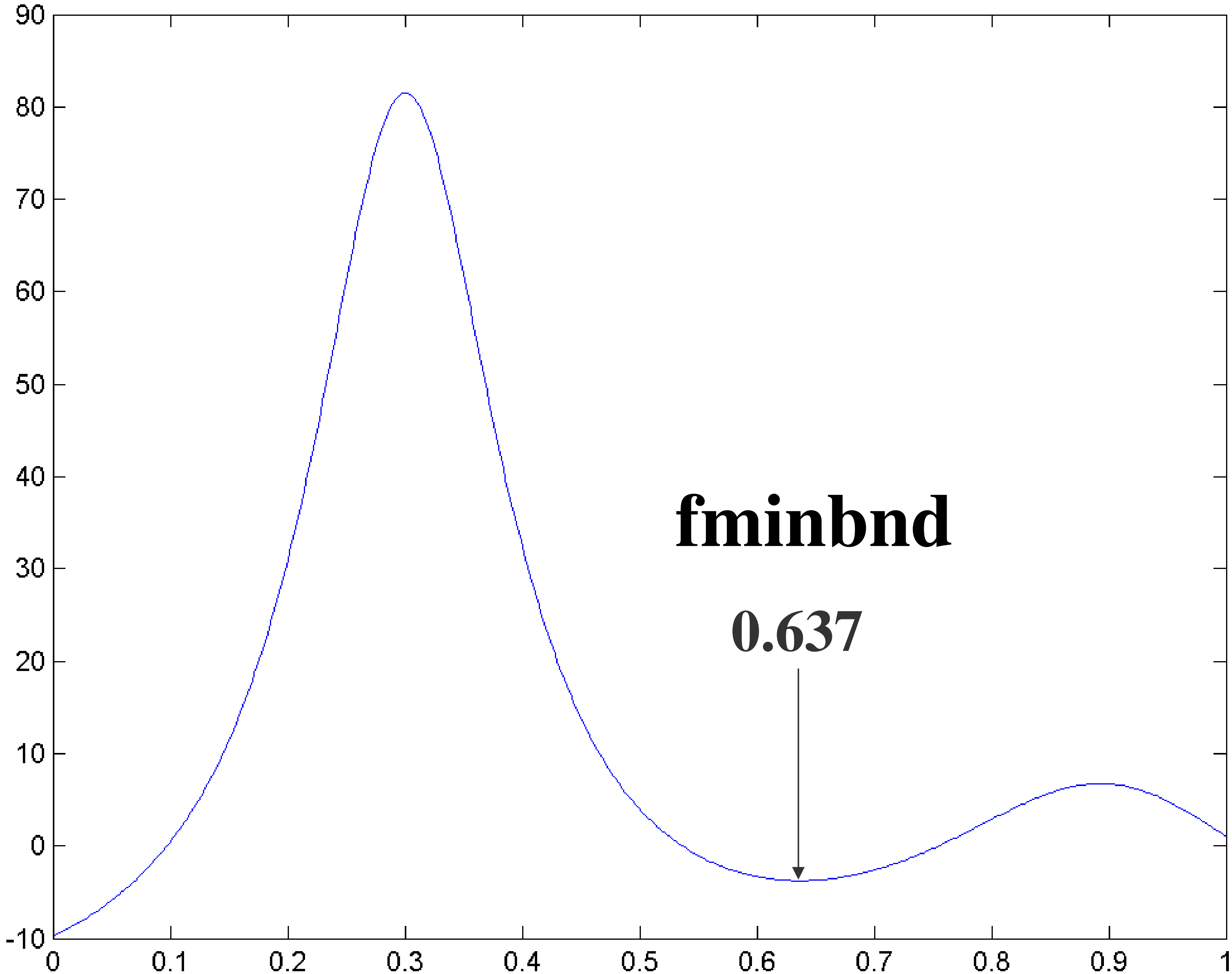
we get ...

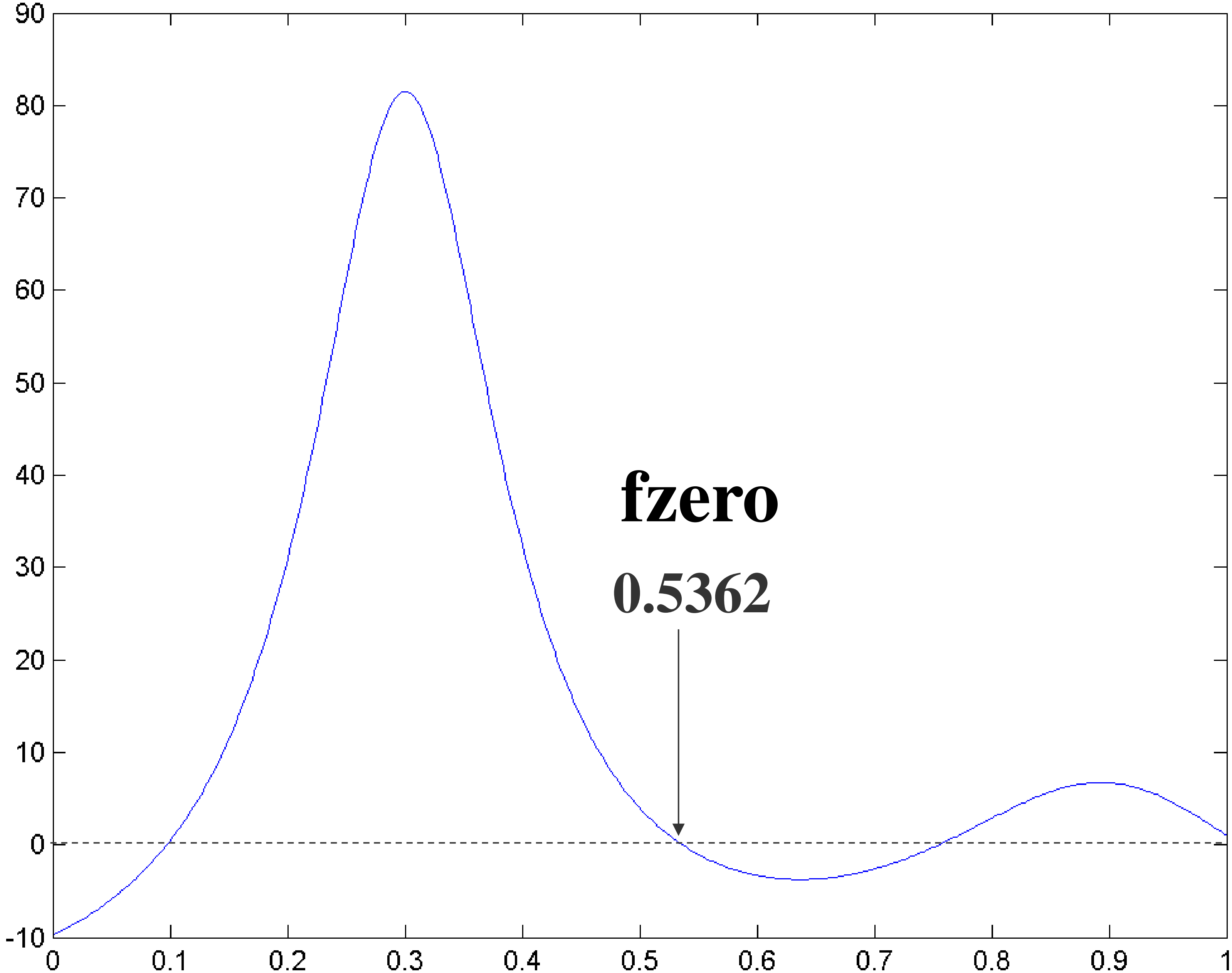

90
80
70
60
50
40
30
20
10
0
-10
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
now there
are some
roots!

fminbnd(‘newhumps', 0.5, 0.7) will find the minimum in the function newhumps between x = 0.5 and x = 0.7

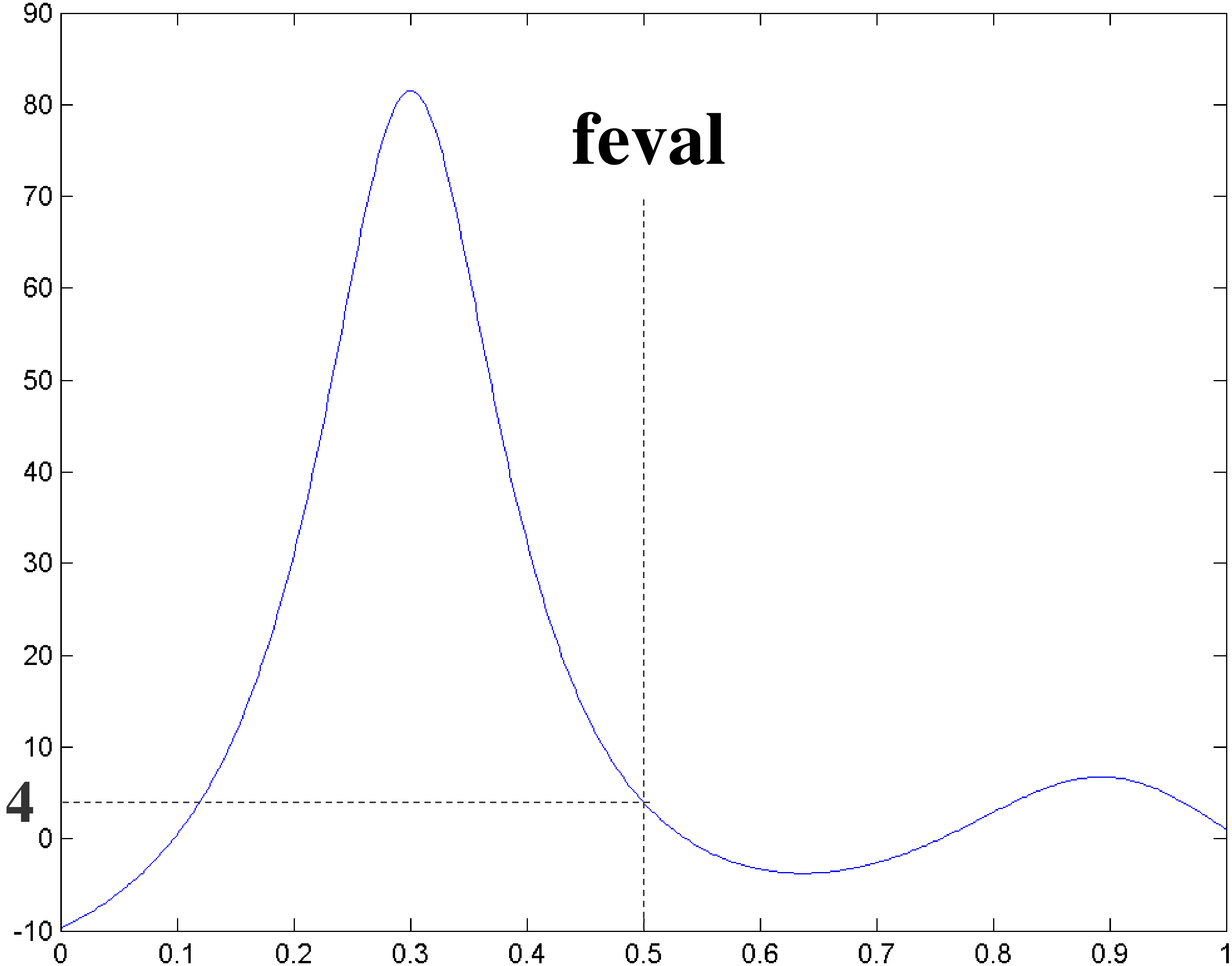
fzero('newhumps', 0.5) will try to find a root near x = 0.5

feval('newhumps', 0.5) will compute the value of newhumps at x = 0.5


fminbnd
0.637
90
80
70
60
50
40
30
20
10
0
-10
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1



fzero
0.5362
90
80
70
60
50
40
30
20
10
0
-10
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


feval
4
90
80
70
60
50
40
30
20
10
0
-10
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

quad(‘newhumps', 0.2, 0.4) will numerically integrate newhumps between x = 0.2 and x = 0.4

quad uses a version of Simpson’s Rule

All these work as well on other functions

fzero(@sin, 0.9*pi)
will try to find a root of sin x near x = 0.9π

@ is a function "handle"
- can use instead of quotes

Returns
ans =
3.14159265358979 ⟵ ~ π as expect

Key point

MATLAB is a powerful programming tool for Engineers, which is worth learning and using