MATLAB: MATrix LABoratory
Matlab provides a technical computing environment designed to support the implementation of computational tasks.

Matlab is an interactive computing environment that enables *numerical computation* and *data visualization*. 
MATLAB

- Matlab is an effective tool.
  - very simple numerical or statistical calculations,
  - some complex statistics,
  - solve simultaneous equations,
  - make a graph, or run and entire simulation program,

- Matlab can solve
  - problems in applied mathematics, physics, chemistry, engineering, finance – almost any application area that deals with complex numerical calculations.
MATLAB

Running MATLAB

- Double-click on the Matlab icon or select Matlab from Start/Programs

MATLAB Windows

- Command Window
- Workspace
- Current Directory
- Command History
Section 2.1
Getting Started

- In Windows or Apple operating systems, click on the desktop icon
- In Unix, type `MATLAB` at the shell prompt
The Default MATLAB Desktop
MATLAB uses a standard windows menu bar

To exit MATLAB use the close icon
Section 2.2
MATLAB Windows

- MATLAB uses several different windows to display data, commands and results.
- They are not necessarily all open at once.
MATLAB Windows

Current Folder Window
Lists files stored in the current directory

Command Window
Enter commands at the prompt

Workspace Window

Command History Window
Records all commands issued in the command window – including mistakes
Let’s look at the windows one at a time
Command Window

- Similar to a scratch pad.
- Once you hit enter, you can't edit any commands.
- You can retype them or use the arrow keys to retrieve commands and edit them before hitting enter again.

Example:

```
>> 5^2
ans =
   25

>> cos(pi)
ans =
   -1

>> A=5
A =
   5

>> B=[1, 2, 3, 4]
B =
   1   2   3   4

>> C=[1 2 3 4; 10 20 30 40; 5 10 15 20]
C =
   1   2   3   4
   10  20  30  40
   5   10  15  20

>> A
A =
   5
```
Records the commands you issue in the command window. When you exit the command window, or when you issue the clc command, the command window is cleared, but the command history remains.
You can transfer commands from the command history to the command window

- Double click on a command
  - It executes immediately
- Click and drag into the command window
  - You can edit the command before executing
When you define variables in the command window, they are listed in the workspace window.
Scalar

Vector

2-D Matrix
The current folder window is a list of files. When you try to load information from a file or try to save information, MATLAB uses the current folder.
2.3.2 Matrices in MATLAB
The basic data type

- Group of numbers arranged into rows and columns
- Single Value (Scalar)
  - Matrix with one row and one column
- Vector (One dimensional matrix)
  - One row or one column
- Matrix (Two dimensional)
You can use MATLAB like you’d use a calculator

```
>> 9 + 10
ans=19
```
An Example Session

```matlab
>> 8/10
ans =  
    0.8000
>> 5*ans
ans =  
    4
>> r=8/10
r =  
    0.8000
>> r
r =  
    0.8000
>> s=20*r
s =  
    16
```
Matlab represents numbers in two forms, fixed point and floating point.

**Fixed point:** Decimal form, with an optional decimal point.
For example: 2.6349  -381 0.00023

**Floating point:** Scientific notation, representing \( m \times 10^e \)
For example: 2.6349 \( \times 10^5 \) is represented as 2.6349e5

The number has two parts:

- **mantissa** \( m \): fixed point number (signed or unsigned), with an optional decimal point (2.6349 in the example above)
- **exponent** \( e \): an integer exponent (signed or unsigned) (5 in the example).

Mantissa and exponent must be separated by the letter e (or E).
Operators

<table>
<thead>
<tr>
<th>Operation</th>
<th>Algebraic form</th>
<th>MATLAB</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addition</td>
<td>$a + b$</td>
<td>a + b</td>
<td>5+3</td>
</tr>
<tr>
<td>Subtraction</td>
<td>$a - b$</td>
<td>a - b</td>
<td>23-12</td>
</tr>
<tr>
<td>Multiplication</td>
<td>$a \times b$</td>
<td>a * b</td>
<td>3.14*0.85</td>
</tr>
<tr>
<td>Right division</td>
<td>$a \div b$</td>
<td>a / b</td>
<td>56/8</td>
</tr>
<tr>
<td>Left division</td>
<td>$b \div a$</td>
<td>a \ b</td>
<td>8\56</td>
</tr>
<tr>
<td>Exponentiation</td>
<td>$a^b$</td>
<td>a ^ b</td>
<td>5^2</td>
</tr>
</tbody>
</table>

“>>” is supplied by Matlab, indicates beginning of the command.

\texttt{ans} = following the completion of the command with the \texttt{Enter} key marks the beginning of the answer.
Operators

Try following operations:

$\gg 3 + 5 + 2$
$\gg 4 \times 22 + 6 \times 48 + 2 \times 82$
$\gg 4 \times 4 \times 4$
$\gg 4^3$
$\gg 56/8$
$\gg 8\backslash 56$
There are rules about the order of operations

1. Parentheses, innermost first
2. Exponentiation (^), left to right
3. Multiplication (*) and division (/ or \) with equal precedence, left to right
4. Addition (+) and subtraction (−) with equal precedence, left to right

When operators in an expression have the same precedence the operations are carried out from left to right. Thus 3 / 4 * 5 is evaluated as ( 3 / 4 ) * 5 and not as 3 / ( 4 * 5 ).
Examples of Precedence

>> 8 + 3*5
ans =
   23
>> 8 + (3*5)
ans =
   23
>>(8 + 3)*5
ans =
   55
>>4^2-12-8/4*2
ans =
   0
>>4^2-12-8/(4*2)
ans =
   3

>> 3*4^2 + 5
ans =
   53
>>(3*4)^2 + 5
ans =
   149
>>27^(1/3) + 32^(0.2)
ans =
   5
>>27^(1/3) + 32^0.2
ans =
   5
>>27^1/3 + 32^0.2
ans =
   11
Parentheses

- Use only ( )
- {} and [ ] mean something different
- MATLAB does not assume operators

\[
5 \times (3+4) \text{ not } 5(3+4)
\]
Precedence of operations
(order of evaluation)

Examples:

\[
\frac{a}{b} + \sqrt{c^3} - bd^2 + \frac{2ab}{b^2 - 4ac}
\]

\[
a + \frac{(b + c^2) \cdot 3f^3}{d + \frac{e - f}{3a}}
\]
Variables

- MATLAB allows you to assign a value to a variable
- A=3
- Should be read as A is assigned a value of 3
- Use the variables in subsequent calculations
Variables and Assignment Statements

Assignment statement:

```markdown
variable = number
variable = expression
variable = input('enter a number')
```

Variable names
1. Must start with a letter
2. May consist only of the letters a-z, digits 0-9, and the underscore character (_)
3. May be as long as you would like, but Matlab only recognizes the first 63 characters
4. *case sensitive*: items, Items, itEms, and ITEMS are all different variable names.
Use the iskeyword function for a list of keywords

<table>
<thead>
<tr>
<th>ans</th>
</tr>
</thead>
<tbody>
<tr>
<td>'break'</td>
</tr>
<tr>
<td>'case'</td>
</tr>
<tr>
<td>'catch'</td>
</tr>
<tr>
<td>'classdef'</td>
</tr>
<tr>
<td>'continue'</td>
</tr>
<tr>
<td>'else'</td>
</tr>
<tr>
<td>'elseif'</td>
</tr>
<tr>
<td>'end'</td>
</tr>
<tr>
<td>'for'</td>
</tr>
<tr>
<td>'function'</td>
</tr>
<tr>
<td>'global'</td>
</tr>
<tr>
<td>'if'</td>
</tr>
<tr>
<td>'otherwise'</td>
</tr>
<tr>
<td>'parfor'</td>
</tr>
<tr>
<td>'persistent'</td>
</tr>
<tr>
<td>'return'</td>
</tr>
<tr>
<td>'spmd'</td>
</tr>
<tr>
<td>'switch'</td>
</tr>
<tr>
<td>'try'</td>
</tr>
<tr>
<td>'while'</td>
</tr>
</tbody>
</table>

Keywords are not acceptable variable names
Practice Exercise 2.2
Which of these names are allowed in MATLAB?

- test
- Test
- if
- mybook
- my_book
- Thisisoneverylongnamebutisitstillallowed?
- xstgroup
- group_one
- zzaAbc
- z34wAwy?12#
- sin
- log \{ bad idea\}
# Special variables and constants

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ans</td>
<td>Temporary variable containing the most recent answer.</td>
</tr>
<tr>
<td>eps</td>
<td>Specifies the accuracy of floating point precision.</td>
</tr>
<tr>
<td>i,j</td>
<td>The imaginary unit $\sqrt{-1}$.</td>
</tr>
<tr>
<td>Inf</td>
<td>Infinity.</td>
</tr>
<tr>
<td>NaN</td>
<td>Indicates an undefined numerical result.</td>
</tr>
<tr>
<td>pi</td>
<td>The number $\pi$.</td>
</tr>
</tbody>
</table>
Variables and Assignment Statements

Example:

```matlab
>> mterm = 60
>> final=80;
>> quiz=60
>> grade = 0.5*mterm+0.1*quiz+0.4*final
```

- Variables: `mterm`, `final`, `quiz`, `grade`
- Results displayed and stored by variable name
- Semicolon at the end of a line (as in the line `>> final=80;`) tells Matlab to evaluate the line but not to display the results
Examples more...

- >> x=5;
- >> y=x+5;
- >> x=2;
- y is still 10 not 7 you have to run >> y=x+5 again to obtain new value of y.
- >> z=z+2 is a correct assignment in MATLAB.

- If you have not supplied a value for xx, Matlab will return a syntax error:
  - >> y=xx+5
  - ??? Undefined function or variable 'xx'.

Variables and Assignment Statements
Variables and Assignment Statements

Examples

Sometimes writing an equation in multiple statements makes the equation more understandable

\[ T_C = \frac{5}{9} (T_F - 32) \]

\[ H(s) = \frac{s^2 + 4s + 13}{s^3 - 2s^2 + 4s + 5} \]

\[
\text{numerator} = s^2 + 4s + 13; \\
\text{denominator} = s^3 - 2s^2 + 4s + 5; \\
H = \text{numerator/denominator};
\]
Example - *Solving for quadratic roots*

\[ 2s^2 + 10s + 12 = 0 \]

find roots of the quadratic equation.

\[
\begin{align*}
>> a &= 2; \\
>> b &= 10; \\
>> c &= 12; \\
>> \text{disc} &= b^2 - 4*a*c; \\
>> x1 &= (-b + \sqrt{\text{disc}}) / (2*a) \\
>> x2 &= (-b - \sqrt{\text{disc}}) / (2*a) \\

x1 &= \\
&-2 \\
x2 &= \\
&-3
\end{align*}
\]
INPUT Prompt for user input.

```python
X = input('enter a number')
enter a number2
X =
2

Enter character strings as follows
Name = input('enter your name :', 's')
enter your name : ali

Name =
ali
```
disp()

There are two general forms of the command disp that are useful in displaying results and annotating them with units or other information:

1. **disp(variable)**: Displays value of *variable* without displaying the variable name.
   
2. **disp(string)**: Displays *string* by stripping off the single quotes and echoing the characters between the quotes.

**String**: A group of *keyboard characters* enclosed in single quote marks ('). The quote marks indicate that the enclosed characters are to represent ASCII text.

```
>> temp=78;
>> disp(temp); disp('degrees F')
78
degrees F
```
There are several commands that can be used to display variables with more control over the form of the display.

<table>
<thead>
<tr>
<th>MATLAB Command</th>
<th>ratio</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>format short</td>
<td>50.8333</td>
<td>4 decimal digits</td>
</tr>
<tr>
<td>format long</td>
<td>50.833333333334</td>
<td>14 decimal digits</td>
</tr>
<tr>
<td>format short e</td>
<td>5.0833e+001</td>
<td>4 decimal digits plus exponent</td>
</tr>
<tr>
<td>format long e</td>
<td>5.0833333333334e+001</td>
<td>14 decimal digits plus exponent</td>
</tr>
<tr>
<td>format short g</td>
<td>50.8333</td>
<td>better of format short or format short e (default), switching for ans &gt; 1000</td>
</tr>
<tr>
<td>format long g</td>
<td>5.0833333333334e+001</td>
<td>better of format long or format long e</td>
</tr>
<tr>
<td>format bank</td>
<td>50.83</td>
<td>2 decimal digits</td>
</tr>
<tr>
<td>format +</td>
<td>+</td>
<td>positive, negative, or zero</td>
</tr>
</tbody>
</table>
Other formats

- Changing the format affects all subsequent displays
  - `format long` results in 14 decimal digits
  - `format bank` results in 2 decimal digits
  - `format short` returns the display to default 4 decimal digits
Really Big and Really Small

- When numbers become too large or too small for MATLAB to display using the default format, it automatically expresses them in scientific notation.
- You can force scientific notation with:
  - `format short e`
  - `format long e`
Common Scale Factor

- For long and short formats, a common scale factor is applied to the entire matrix if some of the elements become very large, or very small. This scale factor is printed along with the scaled values.
Common Scale Factor

```
>> drag=20000;
>> r=0.000001;
>> V=100*0.4470;
>> A=1;
>> cd=drag*2/(r*V^2*A)
   cd =
   2.0019e+007
>> V=0:20:200;
>> v=V*0.447;
>> drag=cd*r*V.^2*A/2;
>> table = [V',drag']
   table =
   1.0e+004 *
   0         0
   0.0009    0.0800
   0.0018    0.3200
   0.0027    0.7200
   0.0036    1.2800
   0.0045    2.0000
   0.0054    2.8800
   0.0063    3.9200
```
Two other formats

- `format +`
- `format rat`
If you save a MATLAB session performed in the command window, all that is saved are the values of the variables you have named.
Variables are saved, not the commands in the command window.
Save either by using the file menu or...

Save with a command in the command window
Commands involving variables:

who: lists the names of defined variables
whos: lists the names and sizes of defined variables
clear: clears all variables, resets default values of special variables
clear var: clears variable var
clc: clears the command window, homes the cursor (moves the prompt to the top line), but does not affect variables.
clf: clears the current figure and thus clears the graph window.

Use commands....
In Matlab, numbers are typically represented in a floating-point representation conforming to a standard established by the IEEE in 1985.

In the IEEE *double-precision* standard used by Matlab, *there are 53 bits (approx. 15 significant digits) in the mantissa and 11 bits in the exponent (m x 2^e)*, for a total of 64 bits to represent a scalar number. This provides a range of values extending from $10^{-308}$ to $10^{308}$. 
Computational Limitations

Two Matlab functions, realmax and realmin, display the largest and the smallest numbers, respectively.

```matlab
>> realmax
ans =
1.7977e+308
>> realmin
ans =
2.2251e-308
```
Command reuse and editing

- Press the up arrow cursor key (↑) to scrolls backward through previous commands. Press Enter to execute the selected command.
- The down arrow cursor key (↓) scrolls forward through commands
- The left (←) and right arrow (→) cursor keys move within a command at the Matlab prompt, allowing the command to be edited.
- The mouse can also be used to reposition the command cursor, by positioning the mouse cursor and pressing the left mouse button.
Command reuse and editing

- Other standard editing keys, such as delete Del, backspace BkSp, home Home, and end End, perform their commonly assigned tasks.
- Once a scrolled or edited command is acceptable, pressing Enter with the cursor anywhere in the command tells Matlab to process it.
- Escape key Esc erases the current command at the prompt.
- Windows copy and paste operations can be used
Getting Help

- `help` — On-line help, display text at command line help, by itself, lists all help topics
- `help topic` provides help for the specified topic
- `help command` provides help for the specified command
- `help help` provides information on use of the help command
- `helpwin` — On-line help, separate window for navigation.
- `helpdesk` — Comprehensive hypertext documentation and troubleshooting
- `help ops`: help about operators and special characters
- F1 + `topic` and help tab from File menu.
Interrupting and Terminating Matlab

- **Ctrl+C**: Interrupts (aborts) processing, but does not terminate Matlab.
- **quit**: Terminates Matlab
- **exit**: Terminates Matlab
- Select **Exit under File menu**: Terminates Matlab