

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL of ELECTRICAL and COMPUTER ENGINEERING

ECE 2026 Spring 2015
Lab #0: Introduction to MATLAB

Date: 5 – 9 Jan. 2015

This lab is for review of MATLAB from the prerequisite course CS-1371. It does not have to be turned in.

The labs will be held in room 2440 of the Klaus building. Your GT login will work, if you specify the “Windows domain” to be AD.

If you have difficulty logging in, visit the web site: www.ece-help.gatech.edu. If you have MATLAB installed on your laptop, you are *encouraged* to use your laptop in lab instead of the lab computers.

Pre-Lab: You should read the Pre-Lab section of the lab and do all the exercises in the Pre-Lab section *before your assigned lab time*.

Verification: The Exercise section of each lab must be completed **during your assigned Lab time** and the steps marked *Instructor Verification* must also be signed off **during the lab time**. One of the laboratory instructors must verify the appropriate steps by signing on the **Instructor Verification** line. When you have completed a step that requires verification, simply raise your hand and demonstrate the step to the TA or instructor. Turn in the completed verification sheet to your TA when you leave the lab.

Lab Homework Questions: The Lab-Homework Sheet has a few lab related questions that can be answered at your own pace. The completed Lab-HW sheet is due at the beginning of the next lab.

Remark about Labs: The predecessor to the three-credit-hour class ECE2026, which was a four-credit-hour class called ECE2025, consisted of labs that require a substantial amount of work to be done outside of lab and an elaborate lab report. To change the workload commensurate with losing one credit hour, we have reworked the labs such that they can be completed in individual lab sessions, without requiring a separate lab report. The in-Lab sessions will be busy, so you will need to come into lab prepared.

Forgeries and plagiarism are a violation of the honor code and will be referred to the Dean of Students for disciplinary action. You are allowed to discuss lab exercises with other students, but you cannot give or receive any written material or electronic files. In addition, you are not allowed to use or copy material from old lab reports from previous semesters. Your submitted work must be your own original work.

1 Pre-Lab

Please read through the information below prior to attending your lab.

1.1 Intelligent Tutoring System (ITS)

During this first lab you should run ITS and answer a few questions. In general, ITS will be used throughout the semester to provide practice on the various concepts covered in ECE2026.

1.2 Overview

MATLAB will be used extensively in all the labs. The primary goal of this lab is to familiarize yourself with using MATLAB. Please read Appendix B: *M-file Programming in MATLAB* for an overview. Here are three specific goals for this lab:

1. Learn basic MATLAB commands and syntax, including the help system.
2. Write and edit your own script files in MATLAB, and run them as commands.
3. Learn a little about advanced programming techniques for MATLAB, i.e., vectorization.

1.3 Movies: MATLAB Tutorials

On the t-square course page, there are a large number of Real-Media movies on basic topics in MATLAB, e.g., colon operator, indexing, functions, etc.

1.4 Getting Started

After logging in, you can start MATLAB by double-clicking on a MATLAB icon, typing `matlab` in a terminal window, or by selecting MATLAB from a menu such as the START menu under Windows. The following steps will introduce you to MATLAB.

- (a) Run the MATLAB help desk by typing `helpdesk`. The help desk provides a hypertext interface to the MATLAB documentation. Two links of interest are Getting Help and Getting Started with MATLAB.
- (b) One of the tabs in the Help Desk is called Demos, where you can see information on getting started and some other basics of MATLAB.
- (c) Explore the MATLAB help capability available at the command line. Try the following:

```
help
help edit
help plot
help colon      %<--- a VERY IMPORTANT notation
help ops
help zeros
help ones
lookfor filter  %<--- keyword search
```

Note: it is possible to force MATLAB to display only one screen-full of information at once by issuing the command `more on`).

- (d) **control-C** will stop the execution of any MATLAB command. For example, using **ctl-C** while `lookfor` is running will force it to stop and print out all the results it has found so far.

1.5 Calculate and Plot

- (a) Use MATLAB as a calculator. Try the following:

```
pi*pi - 10
sin(pi/4)
ans ^ 2      %<--- "ans" holds the last result
```

- (b) Do variable name assignment in MATLAB. Try the following:

```
x = sin( pi/5 );
cos( pi/5 )      %<--- assigned to what?
y = sqrt( 1 - x*x )
ans              %<--- what value is contained in ans?
```

- (c) Complex numbers are natural in MATLAB. The basic operations are supported. Try the following:

```
z = 3 + 4i, w = -3 + 4j
real(z), imag(z)
abs([z,w])      %<-- Vector (or Matrix) constructor
conj(z+w)
angle(z)
exp( j*pi )
exp(j*[ pi/4, 0, -pi/4 ])
```

- (d) Plotting is easy in MATLAB for both real and complex numbers. The basic plot command will plot a vector y versus a vector x. Try the following:

```
x = [-3 -1 0 1 3 ];
y = x.*x - 3*x;
plot( x, y )
z = x + y*sqrt(-1)
plot( z )      %<---- complex values: plot imag vs. real
```

Use `help arith` to learn how the operation `xx.*xx` works when `xx` is a vector; compare array multiplication (dot-star) to matrix multiplication. When unsure about a command, use `help`.

2 Exercise

For the instructor verification, you will have to demonstrate that you understand things in a given subsection by answering questions from your lab instructor (or TA). It is not necessary to do everything in the subsections, i.e., skip parts that you already know. The Instructor Verification is usually placed close to the most important item, i.e., the one most likely to generate questions from the TAs.

2.1 Intelligent Tutoring System (ITS)

During this first lab you should run ITS and answer a few questions:

1. The link to ITS is: <http://its.vip.gatech.edu>. To access ITS, login with your AD username and password (same as for t-square)
2. Answer the few questions in the introductory section of ITS.
3. Then show your TA that you can review your answers.

2.2 MATLAB Array Indexing

- (a) Make sure that you understand the **colon** notation. In particular, explain in words what each of the following MATLAB statements will produce (array length and values):

```
jkl = 0 : 6
nnn = 2 : 4 : 17
mmm = 99 : -1 : 88
ttt = 2 : (1/9) : 4      %<--- How many elements in the ttt vector?
tpi = pi * [ 0:0.1:2 ];
```

- (b) Extracting and/or inserting numbers in a vector is very easy to do. Consider the definition of `xx` in the first line:

```
xx = [ zeros(1,3), linspace(0,1,5), ones(1,4) ]
xx(4:6)
size(xx)
length(xx)
xx(2:2:length(xx))
```

Explain the results echoed from each of the last four lines of the above code.

- (c) Observe the result of the following two assignments, where `xx` was defined in part (b):

```
xx = [ zeros(1,3), linspace(0,1,5), ones(1,4) ];
yy = xx;
yy(4:6) = exp(1)*(1:3)
```

Now write a statement that will take the vector `xx` and replace the even indexed elements (i.e., `xx(2)`, `xx(4)`, etc) with the constant π^e . *Use a vector replacement, not a loop.*

Instructor Verification (separate page)

2.3 MATLAB Array Operations

There are two kinds of multiplication in MATLAB: matrix multiplication and *array* multiplication. Many other operations such as division and exponentiation also have this dual character. MATLAB uses a period to change the behavior from a matrix operator to an array operator, e.g., dot-star (`.*`) instead star (`*`) for multiplication.

- (a) The default is matrix multiplication when the “`*`” symbol is used; execute the following:

```
AA = [ 1, 2; 3, 4; 5, 6; 7, 8]
BB = [ 1, 2, 3; 4, 5, 6]
CC = AA * BB
DD = BB * AA
```

Explain why one of the multiplications fails. In the case where the multiplication succeeds, explain what the dimensions of the resulting product matrix will be.

- (b) In DSP it is often useful to perform an *element-by-element* multiplication, which we will call array multiplication. For example, to multiply one sinusoid by another we would use the “`.*`” operator:

```
nn = 1:9;
qq1 = 7*cos(0.1*pi*nn-pi/2); qq2 = cos(pi*nn);
qq = qq1 .* qq2
zz = qq1 * qq2
```

Explain why the multiplication that attempts to create `zz` fails. Notice that the dimensions of the array-product matrix `qq` are the same as the dimensions of `nn`. Explain the values in the vector `qq2`.

Instructor Verification (separate page)

2.4 MATLAB Script Files

- (a) Experiment with vectors in MATLAB. Think of the vector as a list of numbers. Try the following:

```
xk = cos( pi*(0:11)/4 ); %<---comment: compute cosines
```

How many values of the cosine are stored in the vector `xk`? What is `xk(1)`? Is `xk(0)` defined?

Notes: the semicolon at the end of a statement will suppress the echo to the screen. The text following the % is a comment; it may be omitted.

- (b) (A taste of vectorization) Loops can be written in MATLAB, but they are NOT the most efficient way to get things done. It's better to **always avoid loops** and use the colon notation instead. The following code has a loop that computes values of the cosine function. *Note:* the index of `cc()` must start at 1.

```
cc = [ ];      %<--- initialize the cc vector to be empty
for k=-50:50
    cc(k+51) = cos( pi*k/30 );
end
plot(cc)
```

Explain why it is necessary to write `cc(k+51)` inside the loop. What happens if you use `cc(k)` instead? Also, explain the labels on the x -axis of the plot.

- (c) **Rewrite the computation in the previous without using the loop** by following the style in part (a). Two MATLAB statements plus the plot command should suffice.

- (d) Use the built-in MATLAB editor to create a script file¹ called `mylab1.m` containing the following lines:

```
tt = -5 : 0.01 : 10;
xx = cos( 0.5*pi*tt );
zz = 0.6*exp(-j*pi/4)*exp(j*0.5*pi*tt);
%
%<-- plot the real part, which is a sinusoid
plot( tt, xx, 'b-', tt, real(zz), 'r--' ), grid on
title('Test Plot of a TWO sinusoids')
xlabel('Time (sec)')
```

Explain why the plot of `real(zz)` is a sinusoid. Determine its phase (φ) and amplitude (A) from its definition. Make a calculation of the phase from a time-shift measured on the plot; zoom in to measure a peak location very accurately. Compare this value to the expected value from the formula that defines `zz`.

Instructor Verification (separate page)
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- (e) Run your script from MATLAB. To run the file `mylab1` that you created previously, try

```
mylab1          %<---will run the commands in the file
type mylab1     %<---will type out the contents of
                %    mylab1.m to the screen
```

¹When you save this file or any of your MATLAB files *please do not save to the local hard disk*. Your computer account contains a private networked directory where you can store your own files. Use the MATLAB command `addpath()` to allow MATLAB to “see” your personal directory (usually the Z: drive).

Lab #0 (Does not have to be turned in)

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INSTRUCTOR VERIFICATION SHEET

This page is an example of what would be signed off by your lab grading TA.

Name: _____

Date of Lab: _____

Part 2.1 Answered the “intro” ITS questions, and used the ITS review screen:

Verified: _____ Date/Time: _____

Part 2.2 Vector replacement using the colon operator:

Verified: _____ Date/Time: _____

Part 2.3 Array multiplication versus matrix multiplication:

Verified: _____ Date/Time: _____

Part 2.4(d) Use Euler’s formula, $e^{j\omega t} = \cos(\omega t) + j \sin(\omega t)$, to explain why the plot of $\text{real}(zz)$ is a sinusoid. Determine the amplitude and phase of the sinusoid, and write those values in the space below:

$A =$

$\varphi =$

In the space below, **make a calculation of the phase from time-shift measured on the plot.**

Verified: _____ Date/Time: _____