GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL of ELECTRICAL and COMPUTER ENGINEERING

# ECE 2025 Spring 2003
# Lab #1: Introduction to MATLAB

Date: 13–16 Jan 2003

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This first lab will be held in Van Leer, room 257.
The following week we hope to move the lab to the Bunger-Henry building.

**ECE Account Activation (Windows):** Please verify that your ECE account exists by going to an ECE lab and logging in before your first lab. The login should be your "gtxxxx" number and the *initial* password your complete nine-digit student number. *You must change your password immediately.* If you have difficulty logging in, send an E-mail to

`help@ece.gatech.edu`,
or visit the web site: `www.ece-help.gatech.edu`.

**Pre-Lab:** You should read the Pre-Lab section of the lab and go over all exercises in this section before going to your assigned lab session. You **MUST** answer the online Pre-lab questions by running Pre-Lab #1 in Web-CT at the beginning of your lab session during the week of 13-Jan. You can use MATLAB or any notes you might have but you cannot discuss the exercises with any other students. This Pre-Lab will be a trial run, so you will have 10 minutes at the beginning of your lab session to complete the online Pre-Lab questions.

**Verification:** The Warm-up 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 Report:** It is only necessary to turn in Section 3 as this week's lab report with graphs and explanations. More information on the lab report format can be found on Web-CT under the Information link. You are asked to **label** the axes of your plots and include a title for every plot. In order to keep track of plots, include your plot *inlined* within your report. For more information on how to include figures and plots from MATLAB to your report file, consult the Information link on Web-CT. If you still do not know what is expected, ask your TA who will grade your report.

***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 and you are allowed to consult old lab reports but the submitted work should be original and it should be your own work.***

**Due Date:** The report will **due during the week of 20-Jan. at the start of your lab.** For Sections L12 and L14, the lab report will be due on 27-Jan, because those sections will not have lab on 20-Jan, MLK Day.

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**PRINTING BUDGET:** For the printers in the ECE labs, you have a quota. Please limit your printing to essential items for the labs. If you need to print lecture slides and other large documents, use the central (OIT) printing facilities.

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# 1 Pre-Lab

In this first week, the Pre-Lab will be extremely short and very easy. We will be testing out your ability to do a WebCT on-line quiz, and also some other software for doing the grading. Therefore, make sure that you read through the information below prior to coming to lab.

## 1.1 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: *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.

## 1.2 Movies: MATLAB Tutorials

On the Web-CT course page, there are a large number of Real-media movies on basic topics in MATLAB, e.g., colon operator, indexing, functions, etc. Look for the link with the movie film icon.

## 1.3 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-95/98/NT. The following steps will introduce you to MATLAB.

(a) View the MATLAB introduction by typing `intro` at the MATLAB prompt. This short introduction will demonstrate some of the basics of using MATLAB.

(b) Run the MATLAB help desk by typing `helpdesk`. The help desk provides a hypertext interface to the MATLAB documentation. The MATLAB preferences can be set to use Netscape or Internet Explorer as the browser for help. Two links of interest are **Getting Help** (at the bottom of the right-hand frame), and **Getting Started** which is under MATLAB in the left-hand frame.

(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) Run the MATLAB demos: type `demo` and explore a variety of basic MATLAB commands and plots.

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

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

(f) 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
```

(g) 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 constructor
conj(z+w)
angle(z)
exp( j*pi )
exp(j*[ pi/4, 0, -pi/4 ])
```

# 2 Warm-up

## 2.1 MATLAB Array Indexing

(a) Make sure that you understand the **colon** notation. In particular, explain in words what the following MATLAB code will produce

```
jkl = 0 :  6
jkl = 2 :  4 :  17
jkl = 99 :  -1 :  88
ttt = 2 :  (1/9) :  4
tpi = pi * [ 0:0.1:2 ];
```

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

```
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 the last four lines of the above code.

(c) Observe the result of the following assignments:

```
yy = xx; yy(4:6) = pi*(1:3)
```

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

**Instructor Verification** (separate page)

## 2.2 MATLAB Script Files

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

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

Explain how the different values of 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. (The index of `yy()` must start at 1.) Rewrite this computation without using the loop (follow the style in the previous part).

```
yy = [ ];   %<--- initialize the yy vector to be empty
for k=-5:5
   yy(k+6) = cos( k*pi/5 )
end
yy
```

Explain why it is necessary to write `yy(k+6)`. What happens if you use `yy(k)` instead?

**Instructor Verification** (separate page)

(c) 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 to matrix multiply.

When unsure about a command, use `help`.

(d) Use the built-in MATLAB editor, or an external one such as `EMACS` on UNIX/LINUX, to create a script file called `mylab1.m` containing the following lines:

```
tt = -1 :  0.01 :  1;
xx = cos( 5*pi*tt );
zz = 1.4*exp(j*pi/2)*exp(j*5*pi*tt);
plot( tt, xx, 'b-', tt, real(zz), 'r--' ), grid on
    %<--- plot a sinusoid
title('TEST PLOT of a SINUSOID')
xlabel('TIME (sec)')
```

Note: *Do not save* this file or any of your MATLAB files 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).

Explain why the plot of `real(zz)` is a sinusoid. What is its phase and amplitude ? Make a calculation of the phase from a time-shift measured on the plot.

**Instructor Verification** (separate page)

(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
```

# 3 Laboratory: Plotting Exponentials and Sinusoids with MATLAB

Now you're on your own. **Include a short summary of this Section with plots in your Lab report.** Write a MATLAB script file to do steps (a) through (e) below. Include a listing of the script file with your report.

(a) Generate a time vector `(tt)` to cover a range of $t$ that will exhibit approximately 12 cycles of a sinusoid whose frequency is $975\pi$ rad/sec. Use a definition for `tt` similar to part 2.2(d). If we use $T$ to denote the period of the sinusoids, define the starting time of the vector `tt` to be equal to $-6T$, and the ending time as $6T$. Then the 12 cycles will include $t = 0$. **Finally, make sure that you have at least 25 samples per period of the sinusoidal wave.** In other words, when you use the colon operator to define the time vector, make the increment small enough to generate 25 samples per period.

(b) Generate the following signal

$$x_1(t) = e^{-100|t|} \cos(975\pi t)$$

Make a plot of the signal over the range $-6T \le t \le 6T$. For your final printed output in part (e) below, use `subplot(3,1,1)` to put this plot in the top panel of a three-panel subplot.

```
help subplot
```

(c) Generate the following time-shifted signal

$$x_2(t) = e^{-100|t|} \cos(975\pi(t - 0.02))$$

Make a plot of the signal over the range $-6T \le t \le 6T$. For your final printed output in part (e) below, use `subplot(3,1,2)` to put this plot in the middle panel of a three-panel subplot.

(d) Create a third sinusoid as the sum: $x_3(t) = x_1(t) + x_2(t)$. In MATLAB this amounts to summing the vectors that hold the values of each sinusoid. Make a plot of $x_3(t)$ over the same range of time as used in the plots of part (b). Include this as the third panel in the plot by using `subplot(3,1,3)`.

(e) Before printing the three plots, put a title on each subplot, and include your name in one of the titles. See `help title`, `help print` and `help orient`, especially `orient tall`.

(f) In your summary write-up describe the visual effect associated with the term $e^{-100|t|}$. In addition, comment on why the largest peak value of $x_2(t)$ is less than one.

## 3.1 Theoretical Calculations

The objective in this section is to determine a simple formula for the sum signal as

$$x_3(t) = A_3 e^{-\alpha|t|} \cos(\omega t + \phi_3)$$

where the parameters $A_3$, $\alpha$, $\omega$ and $\phi_3$ must be determined by making measurements on the plot of $x_3(t)$. Remember that the phase of a sinusoid can be calculated after measuring the time location of a positive peak,[1] if we know the frequency.

[1] Usually we say time-delay or time-shift instead of the "time location of a positive peak."

(a) Determine the value of $\alpha$ using algebra.

(b) Make a measurement of the "time-location of a positive peak" on the plot of $x_3(t)$, and write that value for $t_{m_3}$ directly on the plot. It might be best to measure the time location by zooming in on a plot in the MATLAB figure window.

Then calculate (by hand) the phase of the signal $x_3(t)$ by converting the time-shift $t_{m_3}$ to phase. Write this calculation of the phase $\phi_3$ directly on the plot.
*Note:* when doing computations, express phase angles in radians, not degrees!

(c) Measure the largest peak amplitude of $x_3(t)$, and write that value directly on the plot. For calculating $A_3$ from the peak amplitude measurement, some adjustment will have to be done because the largest peak value is not necessarily equal to $A_3$.

(d) Now use the phasor addition theorem to find the phase of the sinusoidal part of $x_3(t)$ from the phases of the sinusoids in $x_1(t)$ and $x_2(t)$. Extract complex amplitudes for the sinusoids in $x_1(t)$ and $x_2(t)$ and carry out a phasor addition to determine the complex amplitude for the sinusoid in $x_3(t)$. Use the complex amplitude for $x_3(t)$ to verify that your previous calculations of $A_3$ and $\phi_3$ were correct.

# Lab #1
# ECE-2025
# Spring-2003
# INSTRUCTOR VERIFICATION SHEET

Turn this page in to your grading TA.

Name: ________________________________________ Date of Lab: __________

Part 2.1 Vector replacement using the colon operator:

Verified:____________________ Date/Time:__________

Part 2.2(b) Write your vectorized statement below.
In addition, explain why it is necessary to write `yy(k+6)` in the loop. What happens if you use `yy(k)` instead?

Verified:____________________ Date/Time:__________

Part 2.2(d) Use Euler's formula, $e^{j\omega t} = \cos(\omega t) + j\sin(\omega t)$, to explain why the plot of `real(zz)` is a sinusoid. What is its amplitude and phase of the sinusoid? In the space below, make a calculation of the phase from time-shift.

Verified:____________________ Date/Time:__________