GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL of ELECTRICAL and COMPUTER ENGINEERING

ECE 2025 Spring 2005
Lab #1: Introduction to MATLAB

Date: 18–24 Jan 2005

The labs will be held in room 216 of 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 an *initial* password.[1] 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.

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 you cannot give or receive written material or electronic files. Your submitted work should be original and it should be your own work.

Due Date: The report will **due during the week of 25-Jan. at the start of your lab.**

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] If you have never used your ECE Windows account before, then the password should be set based on the following formula:
`last 4 digits of gtID# + "!" + 3 character month of birth (Jan, Feb, Mar, etc.) + "$" + 4 digit year of birth + "."` . For example, if your gtID# was 012345678 and you were born 1/1/1970, your password would be: `5678!Jan$1970.`

1 Pre-Lab

Please 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. 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. Two links of interest are **Getting Help** and **Getting Started with 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 print out all results found so far.

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

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

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

(g) 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?
```

(h) 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 ])
```

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 each of the last four lines of the above code.

(c) Observe the result of the following two assignments:

```
yy = xx;  yy(4:6) = exp(1)*(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 π^e. *Use a vector replacement, not a loop.*

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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 array multiplication (`dot-star`) to matrix multiplication.

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.

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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
```

3 Laboratory: Manipulating 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 (d) 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 three cycles of the 20,000-Hz sinusoids defined in the next part, part (b). 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 $-T$, and the ending time as $+2T$. Then the three cycles will include $t = 0$. **Finally, make sure that you have at least 32 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 32 samples per period.

(b) Generate two 20,000-Hz (offset) sinusoids with arbitrary amplitudes and phases:

$$x_1(t) = 512 + A_1 \cos(2\pi(20,000)t + \varphi_1) \qquad x_2(t) = 707 + A_2 \cos(2\pi(20,000)t + \varphi_2)$$

where the values 512 and 707 are constant offsets. Select the value of the amplitudes and phases as follows: Let A_1 be equal to the number formed by the first 3 digits of your student ID # (the one that starts with 9 and contains nine digits) and set $A_2 = 0.9A_1$. For the phases, use the middle three digits of your student ID # to define the angle φ_1 in degrees, and the last three digits equal to define the angle φ_2 in degrees. (Keep in mind that you will then have to convert degrees to radians for use in MATLAB.)

Make a plot of both signals over the range of $-T \leq t \leq 2T$. For your final printed output in part (d) below, use `subplot(3,1,1)` and `subplot(3,1,2)` to make a three-panel subplot that puts both of these plots in the same figure window. See `help subplot`.

Note: it is possible to force all three plots to have the same vertical extent by using MATLAB's `axis` command. For example, `axis([-50,150,-100,1500])` would make the x-axis run from -50 to $+150$, and the y-axis from -100 to $+1500$. Consult `help axis` to obtain more information.

(c) 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 figure window by using `subplot(3,1,3)`.

(d) 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`**.

3.1 Theoretical Calculations

Remember that the phase of a sinusoid can be calculated after measuring the time location of a positive peak,[2] if we know the frequency.

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

(a) Make measurements of the "time-location of a positive peak" and the amplitude from the plots of $x_1(t)$ and $x_2(t)$, and write those values for A_i and t_{m_i} directly on the plots. Then calculate (by hand) the phases of the two signals, $x_1(t)$ and $x_2(t)$, by converting each time-shift t_{m_i} to phase. Write the calculated phases φ_i directly on the plots. Compare your calculated phases to the known phase value used to generate $x_1(t)$ and $x_2(t)$.
Note: when doing computations, express phase angles in radians, not degrees!

(b) The signal $x_3(t)$ is an offset sinusoid of the form:

$$x_3(t) = C_3 + A_3 \cos(\omega t + \varphi_3)$$

and we now want to determine the values of the parameters ω, C_3, A_3 and φ_3. Measure the amplitude and time-shift of $x_3(t)$ directly from the plot and then calculate the phase (φ_3) by hand. Write these values directly on the plot to show how the amplitude, the offset (C_3), and time-shift were measured, and how the phase was calculated.

(c) Now use the phasor addition theorem on the sinusoidal part of the formulas. Carry out a phasor addition of the complex amplitudes for $x_1(t)$ and $x_2(t)$ to determine the complex amplitude for $x_3(t)$. Use the complex amplitude for $x_3(t)$ to verify that your previous calculations of A_3 and φ_3 were correct.

3.2 Complex Amplitude

Write one line of MATLAB code that will generate values of the sinusoid $x_2(t)$ above by using the complex-amplitude representation:

$$x_2(t) = \Re e\{X e^{j\omega t} + Y\}$$

Use constants for X, Y, and ω.

Lab #1
ECE-2025
Spring-2005
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:__________