# Preliminary Engineering Mathematics Course in the Department of Electrical Engineering at Southern University

**Jiecai Luo, Fred Lacy**
Electrical Engineering Department, College of Engineering
Southern University and A & M College

## Abstract

A preliminary Engineering Mathematics course in the Electrical Engineering Department of Southern University is offered for engineering freshman. This course is taught in a way that emphasizes engineering problems in the real world and how math can be used to solve these problems. Fundamental mathematics tools such as linear algebra, matrices, Gauss method for linear equations, MATLAB, complex numbers and their applications, time-domain linear differential equations, and difference equations will be taught. This is one of the great strengths of the Electrical Engineering curriculum at Southern University - emphasis on applying fundamentals to solve real-world problems. In past years, it has been found that if freshmen students get involved with some mathematical tools to solve engineering problems, it greatly helps them to finish undergraduate study successfully. The main contribution in this paper is to demonstrate some of the fundamental mathematical materials at the same time, to emphasize some mathematical fundamentals in engineering applications for other Electrical Engineering classes at the early stage.

## Introduction

It has been observed that a student's successful completion of his (her) engineering design project is dependent of his (her) engineering mathematics background. The Electrical Engineering Department at Southern University and A& M College, in Baton Rouge, Louisiana, over the past twenty years has shown that students majoring in engineering can't make a successful career without a solid Engineering mathematic background. Engineering Mathematics Course (ENGR 340, for short it is referred to as E-math) is a fundamental core course in the College of Engineering of Southern University. In the catalog [6], it states that this course focuses on the application of advanced mathematical techniques in the solution of practical engineering problems, which will include: Matrix operations, Fourier series, Fourier transforms, and Laplace transforms (3 credit hours). This course is taught in a way that shows how engineering problems in the real word are related to mathematics, and how these engineering problems can be solved by adopting different mathematical tools. This is one of the great strengths of Southern University's Electrical Engineering curriculum - emphasis on fundamentals and application to real-world problems.

There is always so much material to be covered in an E-math course, and normally, a one-semester E-math course cannot cover all of the aforementioned material. This could require another semester of the e-math course. This problem could be solved if a new course covering part of the E-math materials such as linear algebra, matrices, complex functions, MATLAB were introduced into the curriculum. On the other hand, after three years of adopting C++ materials for the second college-wide freshman engineering course (ENGR 130), it was found that this material was not suitable for the freshman students. It is urgent to find appropriate materials for the course, and to make sure that the new course materials are suitable for two reasons: first, the materials which include linear algebra, matrices, complex functions, and MATLAB are a transient process from reviewing high school mathematics with engineering application emphasis; second, the freshman will learn how to use their math knowledge with systematic procedures suitable for developing into software algorithms, which is part of E-math. Currently, each engineering curriculum is with compact ABET credits, and the aforementioned new course titled Preliminary Engineering Mathematics will replace the freshman engineering course II (ENGR 130) materials (i.e., C++) with the new materials.

The purpose of this course is to bring the freshman engineering students' analytical and computational skills to a level of competency that would permit them to participate, enjoy, and succeed in subsequent other engineering courses. The specific goals of the course are (a) to make students more comfortable applying the mathematics they have learned in high school or college; (b) to introduce students to many new practical tools through examples; (c) to instruct students in the use of the powerful software MATLAB to solve engineering problems. The main concern in this paper is to show how new materials with engineering systematic procedures are suitable for engineering freshman.

In this paper, some of the course teaching materials will be given, and some discussion will also be provided. This paper is organized as follows: section two gives the course overview and information about some of the course materials, followed by section three which contains some examples, and a discussion or commentary about the examples, and then finally some concluding remarks are given in section four.

## Preliminary Engineering Mathematics Course Overview and Materials

Currently, the course's goal and additional information about the course are given below (ABET standards are used):

**Course Objectives:**

1. To provide students with a working knowledge of (subjects will be covered as time permits)
    a. Introduction to MATLAB;
    b. Linear system equations;
    c. Matrices, vectors and matrix equations;
    d. Inverse matrices, matrix eigenvalues and eigenvectors;
    e. Complex numbers and functions;
    f. Linear differential equations and linear difference equations in time-domain.

1. To enable the students to apply the tools above to basic engineering systems.

**Course Educational Strategies:**

1. The basic teaching method will be the lecture with a rich assortment of examples
2. Students will demonstrate their understanding of the course materials through homework/(projects? Project reports? – what is PR? you should spell it out) assignments, tests and exam.

**ABET category content:** Engineering Science 3 credit or 100%.

**Course Requirements:**

1. Full attendance is required for class hours.
2. Absolutely no make-ups on exam/tests or quizzes. If a student knows that he(she) will not be able to take an (a) exam/test on the given test or exam date, arrangements must be made with his(her) instructor before the date of the exam/test to determine if he(she) needs to take it before or after the given date. If he (she) fails to do this, he(she) will not be allowed to makeup the exam/test under any circumstances. A properly documented legitimate excuse must be given to schedule a makeup.
3. Cheating on any assignment, test or exam will be given a grade of zero on that particular test, exam, or assignment.
4. Late homework assignments will not be accepted.
5. Students are not allowed to leave class while taking a test or exam.
6. Students have a week after an assignment, test or exam is given back to clear up any grading discrepancies.

The materials covered here are part of current E-math (ENGR 340) materials. Most of this information is a review from the mathematics covered in high school. But even with this reviewing process, the problem solving procedures are quite different than the methods taught in high school. Also, the course has an emphasis on the systematic procedures which are suitable to develop MATLAB code to obtain the solutions for problems. In the next section, two examples will be given to show the systematic procedures.

## Some Examples Used in the Class

In this section, two examples are used to illustrate some fundamental differences that distinguish E-math and the mathematics in high school. In general, systematic procedures will be discussed for each of the examples, and then the corresponding MATLAB codes will be developed. Once the students get familiar with the procedures, they will use both systematic procedures by hand and MATLAB codes using a computer to solve a given problem. In the following, examples will be given.

Example one (given in Chapter Two: Linear systems equations): For the general linear equations (1), develop a general systematic procedure and MATLAB code to solve these linear equations:

$$
\begin{array}{ccccccccc}
a_{1,1}x_1 & + & a_{1,2}x_2 & + & \cdots & + & a_{1,n}x_n & = & d_1 \\
a_{2,1}x_1 & + & a_{2,2}x_2 & + & \cdots & + & a_{2,n}x_n & = & d_2 \\
 & & & & & & & \vdots & \\
a_{n,1}x_1 & + & a_{n,2}x_2 & + & \cdots & + & a_{n,n}x_n & = & d_n
\end{array} \quad (1)
$$

Solutions: The Elimination of Variables technique introduced in high school can be normalized to be the linear equations solution method. Using (Naive) Gauss's method, it will be easily to de develop MATLAB code and it is stated as follows. For the given linear equations (1):

1. Using the first equation in equations (1) to eliminate one of the unknowns $x_1$ from all other equations (2 through n) to form new linear equations (2) as given below:

$$
\begin{array}{ccccccccc}
a_{1,1}x_1 & + & a_{1,2}x_2 & + & \cdots & + & a_{1,n}x_n & = & d_1 \\
 & + & a'_{2,2}x_2 & + & \cdots & + & a'_{2,n}x_n & = & d'_2 \\
 & & & & & & & \vdots & \\
 & + & a'_{n,2}x_2 & + & \cdots & + & a'_{n,n}x_n & = & d'_n
\end{array} \quad (2)
$$

2. Using the second equation in (2) to eliminate one of the unknowns $x_2$ from all other equations (3 through n) to form new linear equations (3) as given below:

$$
\begin{array}{cccccccccc}
a_{1,1}x_1 & + & a_{1,2}x_2 & + & & + & \cdots & + & a_{1,n}x_n & = & d_1 \\
 & & a'_{2,2}x_2 & + & & + & \cdots & + & a'_{2,n}x_n & = & d'_2 \\
 & & & & +a''_{3,3}x_3 & + & \cdots & + & a''_{2,n}x_n & = & d''_2 \\
 & & & & & & & & & \vdots & \\
 & & & & +a''_{n,3}x_3 & + & \cdots & + & a''_{n,n}x_n & = & d''_n
\end{array} \quad (3)
$$

3. Using the third equation in (3) to eliminate one of the unknowns $x_3$ from all other equations (4 through n) to form new linear equations:
4. Continue until only one equation is remaining.
5. The last equation with only one variable $x_n$ left as

$$
\begin{array}{lllllllll}
a_{1,1}x_1 & + & a_{1,2}x_2 & + & & + & \cdots & + & a_{1,n}x_n & = & d_1 \\
 & & a'_{2,2}x_2 & + & & + & \cdots & + & a'_{2,n}x_n & = & d'_2 \\
 & & & & +a''_{3,3}x_3 & + & \cdots & + & a''_{2,n}x_n & = & d''_2 \\
 & & & & & & & & \vdots & & \\
 & & & & & & & & a^{n-1}_{n,n}x_n & = & d^{n-1}_n
\end{array} \qquad (4)
$$

According to the linear equations (1), the new equivalent linear equations (4) are easily solved by taking back substitution procedure: first to get an answer for $x_n$ by $x_n = \frac{d_n^{(n-1)}}{a_n^{(n-1)}}$.

This result can be back-substituted into the ($n$-1)-th equation to solve $x_{n-1}$. The procedure, which is repeated to evaluate the remaining *x's*, can be represented by the following formula:

$$
x_i = \frac{d_i^{(i-1)} - \sum_{j=i+1}^{n} a_{i,j}^{(i-1)} x_j}{a_{i,i}^{(i-1)}}, i = n-1, n-2, ...1 \qquad (5)
$$

With this procedure, the MATLAB code is developed as

```
% This m file for solving linear equations with
% Gauss' method.
% input:
% A = coefficients of the linear equations
% b = right hand side vector
%output:
% x= solution vector
clear;
A=input('input coefficients A=');
b=input('input vector b=');
[m, n] = size(A);
if m =n, error('Matrix A must be square'); end;
nb = n+1;
Aug = [A b];
disp('augment matrix [A b]=')
disp(Aug)
% forward elimination
disp('do Gauss' Method ')
for k = 1:n-1;
for i = k+1:n;
factor = Aug(i,k)/Aug(k,k);
```

```
new_row = factor * Aug(k,k:nb);
Aug(i,k:nb) = Aug(i,k:nb)-factor*Aug(k,k:nb);
end;
disp(Aug);
end;
x = zeros(n,1);
x(n) = Aug(n,nb)/Aug(n,n);
for i = n-1:-1:1;
x(i) = (Aug(i,nb)-Aug(i,i+1:n)*x(i+1:n))/Aug(i,i);
end;
disp('solutions x=')
x
disp('final check A*x = B')
A*x
b
```

With the systematic procedure and MATLAB code now complete, example two will now be considered.

Example Two: Use the systematic procedure by hand and MATLAB code to determine the solution for equations (6).

$$\begin{array}{lclclclcr} 7x_1 & + & 3.1x_2 & + & 2.3x_3 & + & 0.7x_4 & = & 5.1 \\ -1.2x_1 & + & 9.1x_2 & + & 1.3x_3 & + & 2.1x_4 & = & 3.2 \\ 0.85x_1 & - & 0.13x_2 & + & 9.5x_3 & - & 1.8x_4 & = & 10.1 \\ 1.1x_1 & + & 2.3x_2 & + & 1.5x_3 & + & 10.7x_4 & = & -4.5 \end{array} \qquad (6)$$

Solution: Using the systematic procedure by hand the following is found: (a) eliminate all $x_1$ variables except for those in the first equation as below

$$\begin{array}{lclclclcr} 7x_1 & + & 3.1x_2 & + & 2.3x_3 & + & 0.7x_4 & = & 5.1 \\ & & 9.6314x_2 & - & 0.9057x_3 & + & 2.2200x_4 & = & 4.0743 \\ & & -0.5064x_2 & + & 9.2207x_3 & - & 1.8850x_4 & = & 9.4807 \\ & & 1.8129x_2 & + & 1.1386x_3 & + & 10.5900x_4 & = & -5.3014 \end{array} \qquad (7)$$

(b) eliminate all $x_2$ variables except for those in the first and second equations as below

$$
\begin{aligned}
7x_1 \; + \; 3.1x_2 \; &+ \; 2.3x_3 \; + \; 0.7x_4 = 5.1 \\
9.6314x_2 \; &- \; 0.9057x_3 \; + \; 2.2200x_4 = 4.0743 \\
&\quad 9.1731x_3 \; - \; 1.7683x_4 = 9.6949 \\
&\quad 1.3090x_3 \; + \; 10.1721x_4 = -6.0683
\end{aligned} \tag{8}
$$

(c) eliminate the $x_3$ variable in the last equation, then

$$
\begin{aligned}
7x_1 \; + \; 3.1x_2 \; &+ \; 2.3x_3 \; + \; 0.7x_4 = 5.1 \\
9.6314x_2 \; &- \; 0.9057x_3 \; + \; 2.2200x_4 = 4.0743 \\
&\quad 9.1731x_3 \; - \; 1.7683x_4 = 9.6949 \\
&\quad 10.4245x_4 = -7.4518
\end{aligned} \tag{9}
$$

Then by the back substitution method, the solution is

$$x_4 = -0.7148, x_3 = 0.9191, x_2 = 0.6742 \text{and } x_1 = 0.1995.$$

Secondly, by running the MATLAB code, the following is obtained

```
input matrix A=[7 3.1 2.3 0.7;
-1.2 9.1 -1.3 2.1;
0.85 -0.13 9.5 -1.8;
1.1 2.3 1.5 10.7]
input vector b=[5.1;3.2;10.1;-4.5]
augment matrix [A b]=
7.0000 3.1000 2.3000 0.7000 5.1000
-1.2000 9.1000 -1.3000 2.1000 3.2000
0.8500 -0.1300 9.5000 -1.8000 10.1000
1.1000 2.3000 1.5000 10.7000 -4.5000
Aug =
7.0000 3.1000 2.3000 0.7000 5.1000
0 9.6314 -0.9057 2.2200 4.0743
0 0 9.1731 -1.7683 9.6949
0 0 0.0000 10.4245 -7.4518
solutions x=
0.1995
0.6742
0.9191
-0.7148
```

As mentioned in section one, the examples provided here show the different emphasis through comparisons to high school mathematics. One of purposes in this course is to develop a systematic procedure for problem solving strategies, and then try to use computers to help find solutions for a given problem.

## Conclusions

This new preliminary engineering mathematics course is suitable for freshman engineering students. Past evidence and experiences have shown that if freshmen get interested in using mathematical tools to solve engineering problem, it will greatly help them to successfully finish their undergraduate studies. By introducing these topics at this early state, this course will show freshmen engineering students the differences of E-math and high school mathematics.

### References


1. Jiecai Luo and P. Bhattacharya, "Engineering Mathematics Course in Department of Electrical Engineering at Southern University," GSW-ASEE 2008.
2. Erwin Keryszig, "**Advanced Engineering Mathematics**, 9th Edition," John Wiley & Sons, INC., 2006.
3. B. P. Lathi, "**Linear Systems and Signals**, 2nd Edition," Oxford University Press, 2005.
4. Ross L. Finney, M. D. Weir and Frank R. Giordana, "**Thomas's Calculus Early Transcendental**, 10th Edition," Addison Wesley, 2001.
5. Zoran Gajic, "**Linear Dynamic Systems and Signals**," Prentice Hall, 2003.
6. **2006 – 2008 Catalog**, Southern University and A & M College, Baton Rouge, LA 70813.
7. M.Greenberg, "**Advanced Engineering Mathematics**", 2nd Edition, Prentice Hall, 1998.
8. P. Oneil, "Advanced Engineering Mathematics", 5th Edition, Thomson/Brooks/Cole, 2003.



JIECAI LUO
Dr. Luo currently serves as Associate Professor of Electrical Engineering at Southern University Baton Rouge. His research interest includes Signal and Image Processing, Artificial-Intelligence, Data fusion and Optimal Control Systems. Email: jluo@engr.subr.edu

FRED LACY
Dr. Fred Lacy is currently an Associate Professor in the Electrical Engineering Department at Southern University. His current research interests include nanotechnology, thin films, and sensor fabrication and characterization.