

ME 352, Numerical Methods in Engineering
Mechanical and Materials Engineering Department

Fall 2007
Portland State University

ME 352 is a required course for the BSME program, and it is typically taken in the third year. The primary goal is to provide mechanical engineering majors with a basic knowledge of numerical methods including: root-finding, elementary numerical linear algebra, solving systems of linear equations, curve fitting, numerical quadrature, and numerical solution to ordinary differential equations. MATLAB is the software environment used for implementation and application of these numerical methods. The numerical techniques learned in this course enable students to work with mathematical models of technology and systems. Homework and projects in other courses in the BSME curriculum require the mathematical and numerical skills obtained in ME 352.

Prerequisites

Admission to upper division MCECS Program, EAS 101, Math 256

Instructor and Teaching Assistant

Instructor: Gerald Recktenwald, Associate Professor, Mechanical Engineering Department
Engineering Building Suite 400, 725-4290, gerry@me.pdx.edu
Web site for the course: web.cecs.pdx.edu/~gerry/class/ME352

Required Textbook

G.W. Recktenwald, *Numerical Methods with MATLAB: Implementations and Applications*.
2000, Prentice-Hall, Upper Saddle River, NJ.

Supplemental material for the book is at web.cecs.pdx.edu/~gerry/nmm

Policies

Homework is due at the beginning of class on the due date. Penalties for late homework are listed at <http://web.cecs.pdx.edu/~gerry/class/ME352/homework>.

Two, twenty-minute, in-class quizzes will be given. The midterm exam will last one class period. The final exam will be comprehensive. All quizzes and exams are mandatory. Discuss any potential conflicts *well before the exam dates*. **There will be no make-up quizzes or exams.**

If you have a disability and are in need of academic accommodations, please notify me (G. Recktenwald) immediately to arrange needed supports. If you need information about disabilities, please contact the Disability Resource Center on campus at 503-725-4150.

Students are expected to turn in homework assignments that are substantially the result of their own work. Study groups, discussion of assignments among students, collective brainstorming for solutions, and sharing of advice are encouraged. Copying of assignments, computer files, graphs, or other means of duplicating material that is turned in for grading is *forbidden*. *Cheating on exams will result in a zero grade for the exam.*

Learning Objectives

The Learning Objectives are skills that you should obtain by the end of class. If you can do all of the following activities very well, then you will likely get an “A” grade.

- The ability to write programs in MATLAB that involve loops, logical block constructs (`if...else`), plotting, and simple file input/output. The ability to write programs that evaluate and plot analytical functions. The ability to translate numerical algorithms to correct MATLAB programs.
- The ability to write MATLAB programs to evaluate a truncated infinite series. The ability to distinguish between the effects of truncation error and roundoff error in evaluating a finite number of terms in an infinite series.
- The ability to define machine precision, underflow limit, and overflow limit and identify the built-in MATLAB variables for these concepts. The ability to use an understanding of machine precision and roundoff errors to write MATLAB code for correctly testing convergence of iterative sequences. The ability to read and interpret expert MATLAB code (such as that found in the built-in toolbox, or other computational libraries) that uses convergence tests involving machine precision.
- The ability to transform an engineering equation involving one unknown into the canonical root-finding form: $f(x) = 0$. The ability to perform manual iterations of the bisection method, Newton’s method, and the secant method. The ability to apply MATLAB programs for finding the zeros of a function of one variable.
- The ability to manually perform addition, subtraction, and multiplication operations on vectors and matrices. The ability to manually compute vector norms. The ability to use all of these linear algebra operations in MATLAB programs.
- The ability to set up and solve linear systems of equations. The ability to manually perform Gaussian elimination and backward substitution on small systems. The ability to use MATLAB’s backslash operator to correctly compute the solution to a system of linear equations. The ability to interpret the condition number of coefficient matrix for a linear system of equations. The ability to compute and interpret the residual of a linear system of equations.
- The ability to use MATLAB programs to perform curve fits of data to polynomials and linear combinations of arbitrary functions. The ability to use a residual plot from a curve fit as an indicator of whether a better curve fit might be obtainable.
- The ability to manually apply Euler’s method, Heun’s method, and the fourth order Runge-Kutta method to advance a single ordinary differential equation for one or two steps of the independent variable. The ability to use MATLAB programs to obtain numerical solutions to ordinary differential equations.

Grading

Cumulative grades will be based on the following weights: Homework 20%, two Quizzes 10% each, Midterm Exam 30%, Final Exam 30%.

Letter grades are assigned according to cumulative score s as follows: A: $s > 0.85$; B: $0.75 < s \leq 0.85$; C: $0.65 < s \leq 0.75$; D: $0.5 < s \leq 0.65$; F: $s < 0.5$. \pm letter grades are determined from the shape of the distribution according to these criteria

- Breaks in the distribution are sought out so that students with close numerical scores receive similar or the same grade.
- Students with strong upward or downward trends in test scores have their grades adjusted by + or – according to the trend.

Additional References

The following texts are not required. They provide related or alternative coverage to that in the required text.

MATLAB *Student Version Release 14*, 2004, The MathWorks, Inc., Natick, MA. The Student Version includes MATLAB version 7, Simulink 6, and key functions from the Symbolic Math Toolbox. It is available at the PSU Bookstore, and can be ordered directly from the MathWorks at www.mathworks.com.

Fausett, Laurene V. *Applied Numerical Methods Using MATLAB*, 1999, Prentice-Hall, Upper Saddle River, NJ.

Mathews, John H. and Kurtis D. Fink, *Numerical Methods Using MATLAB*, 1999, Prentice-Hall, Upper Saddle River, NJ

Moler, Cleve B., *Numerical Computing with MATLAB*, 2004, SIAM, Philadelphia, PA. Chapters can be downloaded from <http://www.mathworks.com/moler/>

Chapra, Steven C. *Applied Numerical Methods with MATLAB*, 2005, McGraw-Hill, NY.

Chapra, Steven C. and Canale, Raymond P. *Numerical Methods for Engineers*, fifth ed., 2006, McGraw-Hill, NY.

Schilling, Robert J., and Harris, Sandra L., *Applied Numerical Methods for Engineers*, 2000 Brooks/Cole, Pacific Grove, CA.

Students interested in books that focus more on MATLAB programming than numerical methods might consider these texts:

Chapman, Steven J., *MATLAB Programming for Engineers 2002*, Brooks/Cole, Pacific Grove, CA.

Hanselman, Duane, and Littlefield, Bruce, *Mastering MATLAB 7*, 2005, Prentice-Hall, Upper Saddle River, NJ.

Higham, Desmond J., and Higham, Nicholas J., *MATLAB Guide*, second ed., 2005, SIAM, Philadelphia, PA.

Course Outline

The course outline lists the topics and the corresponding sections of the textbook that will be covered in this class. Class lectures may not always fit neatly into the time periods given in the outline, so students should consider the outline as a tentative guide to class lectures. In particular, the date of the midterm exams will be confirmed by an announcement in lecture. Do not claim that you missed the exam because it did not occur at the date implied by this outline!

The pace of the course material picks up considerably toward the end of the class. This is intentional. Most students taking ME 352 have just entered the upper division of the College, and many are attending PSU for the first time. In addition, most students do not have prior exposure to MATLAB. To allow for an initial period of adjustment, as well as to make sure everyone starts on a solid footing, the first five weeks of the class move at a more methodical pace. Students are advised to use this time wisely by rediscovering their programming skills, learning how to use the MCECS computing laboratories, and by refreshing any rusty mathematics. By the midterm, I assume that the adjustment period is over and students are ready to move at a pace that is consistent with the expectations of upper division curriculum.

Class	Topic	Reading
1	Course overview, MCECS Network, Introduction to MATLAB	Chapter 1, §§2.1 — 2.2.2
2	Creating and manipulating MATLAB variables, plotting	§2.2.3 — 2.5
3	MATLAB programming: scripts, functions, text output	§§3.1 — 3.3
4	MATLAB programming: flow control, vectorization	§§3.4 — 3.5
5	Documenting m-files, review of MATLAB	§4.1
6	Unavoidable errors in computing, overview of root-finding	§§5.1 — 5.2, §6.1
7	Root-finding: bracketing, fixed point iteration, bisection	§§6.1 — 6.3
8	Root-finding: bisection, Newton's method, secant method	§§6.4 — 6.5
9	Root-finding: <code>fzero</code> , roots of polynomials	§§6.5 — 6.7
10	Midterm Exam	
11	Review of linear algebra: vectors and matrices	§§7.1 — 7.2
12	Review of linear algebra: mathematical properties of vectors and matrices, special matrices	§§7.3 — 7.4
13	Solving systems of equations	§8.1
14	Gaussian elimination	§8.2
15	Limitations on numerical solutions to $Ax = b$	§8.3
16	Curve fitting	§9.1
17	Curve fitting	§9.2.1 — 9.2.2,
18	Ordinary differential equations	§§12.1 —12.2
19	Ordinary differential equations	§§12.2 —12.4