# ME 163
# APPLIED DIFFERENTIAL EQUATIONS
## SPRING TERM 2000

### INSTRUCTOR

Alfred Clark, Jr., Hopeman 329, x54078, clark@me.rochester.edu

### UNDERGRADUATE TEACHING ASSISTANTS

Douglas Briller and Dan Grabski

### OFFICE HOURS

MTWThF 1600-1800
Office hours for TA's to be announced in class. Any temporary changes in office hours will be posted on the web site for the course.

### CLASS SCHEDULE

MWF 900 - 950 in Morey 321
Th 1410 - 1500 in Dewey 1101 on a non-exam day
Th 1400 - 1515 in Dewey 1101 on an exam day

Each week there will be three hours of new material and one hour of examples and comments on the homework. Rather than presenting the examples and homework comments in a separately scheduled recitation, all such material will be integrated into the four meeting hours each week. The total time of meeting is the same as the traditional three classes plus one recitation, but the scheduling this way is much more flexible. The full 75 minutes on Thursday will be used only on the two exam days.

The other relevant room for the course is the M.E. Department Mac Lab in room 05 of the basement of the Hopeman Building. This is a convenient place to do the computer work for this course. A schedule for the lab will be given in a separate handout.

### COURSE WEB SITE

All course handouts, including homework assignments, homework solutions, descriptions, schedules, Mathematica notebooks, and movies will be put on the course web site. The web site also has the course calendar, which will be updated weekly. Perhaps the most important feature on

the web site is the bulletin board, which you will see as soon as you access the site. This bulletin board will be used for such announcements as changes in due dates or corrections to homework problems, so you should check it frequently. More detailed information about the web site is available on the site. The URL for the site is http://www.me.rochester.edu/courses/ME163.

## PREREQUISITES

The prerequisite for this course is calculus (MTH 161 and 162, or MTH 141-143). Some of the applications to be presented will be more meaningful if you have some background in basic mechanics (PHY 121 or ME 121).

## ASSIGNMENTS AND EXAMS

There will be 11 homework assignments, two 75-minute exams, a project, and a three-hour final exam. The TA's will grade the homework, and I will grade all the exams and the project. The grading weights will be 35% for the homework, 10% each for the 75-minute exams, 10% for the project, and 35% for the final exam. The lowest homework grade will be dropped. The homeworks will be due on Fridays. The due dates are Jan 14, Jan. 21, Jan. 28, Feb. 4, Feb. 18, Feb. 25, Mar. 3, Mar. 17, Mar. 24, Apr. 7, and Apr. 14. More information on homework policies is given at the end of this document. The exam dates and the project due date are given below. **All exams will be open book and open notes.**

| | | |
|---|---|---|
| First Exam | Thursday February 10 | 1400 - 1515 |
| Second Exam | Thursday March 30 | 1400 - 1515 |
| Project Due | Wednesday April 26 | 1800 |
| Final Exam | Saturday May 6 | 1600 - 1900 |

## COMPUTER WORK

On every assignment, there will be at least one problem requiring some computer work. The work will be done with Mathematica, which is available on the 20 power Macintoshes in the Mac Lab in the basement of Hopeman, as well as at other locations on campus. No prior experience with Mathematica is assumed, and the first few assignments will have simple problems which will give you a chance to become familiar with Mathematica. More detailed information on the computer work and the computer lab is given at the end of this handout.

## PROJECT

The project for the course will take the place of homework during the last one-and-one-half weeks of classes. It will be handed out approximately a month before the end of classes, and detailed instructions will be given then. You will have the choice of working alone or in groups of two. The project will involve some substantial computer work with Mathematica, and it will deal with an engineering or scientific application of ordinary differential equations. If you want some idea of what the project problem will be like, look at the examples from three previous years on the web site for the course, or look at the examples on pages 328 and 829 in the text.

## TEXTBOOK

The required textbook for the course is **Fundamentals of Differential Equations and Boundary Value Problems**, R. K. Nagle, E. B. Saff and A.D. Snider, third edition, Addison-Wesley, 1999. There will be assigned reading in this text, and most of the homework problems will be assigned from the text. The lectures will follow the text in general, but will be different – sometimes quite different – in detail. In particular, many of the applications covered in class are not in the text.

## BOOKS ON RESERVE

Differential equations is an old and well-developed subject, and the literature is extensive. The list below contains just a few selected general references. References to some specialized topics will be given during the semester. All of the books listed below are on reserve in Carlson, with the exception of the Mathematica references. Those references are available for use in the Mac Lab.

Textbook and Other References at the Same Level as the Course

The first book below is our text. The second edition of the text was used in this course in several previous years. The second book is the text used last year in this course. The next three books are similar to the text in style and in level of difficulty. The last book has an informal style and a strong emphasis on applications. In most cases our text should be adequate, but if you are having trouble with a point, you might want to try one of the other three for a different presentation.

**Fundamentals of Differential Equations and Boundary Value Problems**, R. K. Nagle, E. B. Saff and A.D. Snider, third edition, Addison-Wesley, 1999.

**Introduction to Ordinary Differential Equations with Mathematica**, by Alfred Gray, Michael Mezzino, and Mark Pinsky, Springer, 1997.

**Elementary Differential Equations**, sixth edition, W.E. Boyce and R.C. DiPrima, John Wiley, 1997.

**Elementary Differential Equations with Applications**, third edition, C.H. Edwards, Jr. and D. E. Penney, Prentice Hall, 1994.

**Modern Differential Equations**, M.L. Abell and J.P. Braselton, Harcourt Brace 1996.

**Differential Equations – A Modeling Perspective**, R.L. Borelli and C.S. Coleman, John Wiley, 1998.

References on Mathematica

The first two books below are excellent references for beginners in Mathematica. They both have many worked examples. The third book is the standard reference on Mathematica by the developers of it. It is comprehensive and intimidating. Try the other two books first. The

fourth book deals specifically with the use of Mathematica to solve differential equations, and it has many useful examples.

**The Beginners Guide to Mathematica Version 3**, Jerry Glynn and Theodore Gray, Cambridge University Press, 1997. Although this was written for version 3 of Mathematica, it is still very useful for version 4. A new edition for version 4 should be out any time.

**Mathematica by Example**, Second Edition, Martha Abell and James Braselton, Academic Press, 1997.

**The Mathematica Book**, Stephen Wolfram, fourth edition, Cambridge University Press, 1999.

**Differential Equations with Mathematica**, second edition, K.R. Coombes, B.R. Hunt, R.L. Lipsman, J.E. Osborn, and G.J. Stuck, John Wiley, 1997.

References at a Higher Level than the Course

If you wish to pursue any topics in greater depth, you may want to look at some more advanced books on differential equations. There are many such books. The four listed below are especially useful and interesting. The book by Braun is at a level only slightly higher than the course. It is notable for the many interesting applications presented in detail. The book by Simmons has more advanced topics in it than Braun, and in addition it has many historical notes on the subject. The book by Birkhoff and Rota is quite advanced and pays the most attention to the mathematical foundations of the subject. It is very clearly written. The last book, by Strogatz, is a very nice introduction to Dynamical Systems and Chaos. It will be relevant to the last part of our course.

**Differential Equations and Their Applications**, fourth edition, Martin Braun, Springer-Verlag, 1993.

**Differential Equations with Applications and Historical Notes**, second edition, George F. Simmons, McGraw-Hill, 1991.

**Ordinary Differential Equations**, fourth edition, Garrett Birkhoff and Gian-Carlo Rota, John Wiley, 1989.

**Nonlinear Dynamics and Chaos**, S. H. Strogatz, Addison-Wesley, 1994.

## COURSE OUTLINE

The approximate time to be spent on each topic is given, along with the relevant chapters in the text. Detailed references to specific sections of the text will be given with each weekly assignment.

1. Introduction (Chapter 1; 1 week)

Examples of physical problems leading to differential equations; basic concepts and terminology. Brief introduction to Mathematica.

2. First-Order Equations (Chapters 2 and 3; 3 weeks)

Separable equations; exact equations; linear equations; using Mathematica to solve first order equations; solution curves and direction fields; numerical solution by the Euler method. Case studies: population models; free fall and the drag law; heating and cooling of buildings.

3. Linear Second Order Equations (Chapter 4; 6 weeks)

Examples and basic concepts; homogeneous equations; homogeneous equations with constant coefficients; complex numbers; constant coefficient equations with complex roots; unforced vibrations; inhomogeneous constant coefficient equations; sinusoidally forced vibrations; equidimensional equation; reduction of order; variation of parameters. Case studies: measuring parameters in vibrating systems; switch design; automobile suspension.

4. Systems of First-Order Equations (Chapters 5 and 12; 4 weeks)

Examples of problems leading to systems of equations; phase plane; linear constant coefficient systems; using Mathematica to solve systems; general discussion of equilibrium and stability in mechanical systems; equilibrium and stability in linear systems; equilibrium and stability in nonlinear systems; oscillatory behavior in nonlinear systems. Case studies: SIR models of epidemics; dynamics of disease; predator-prey models; the van der Pol oscillator; nonlinear vehicle suspension; introduction to chaos.

## COURSE CALENDAR

The calendar at the end of this handout shows the detailed schedule for the semester. For each class meeting, there is given the topic to be covered, the relevant sections in the class notes, and the relevant sections in the text. The homework due dates are also given, along with the sections of class notes covered by each homework. The topics of the computer demos are also listed. All of this suggests a precision which is not really possible – that is, there inevitably will be deviations from this schedule, although they will not be large. The homework assignment each week will give the up-to-date calendar for that week, and the course calendar on the web site will be updated every week. Any changes in due dates for homeworks or changes in exam dates will be announced in class and also posted on the web site bulletin board.

## POLICIES ON HOMEWORK

The purpose of these rules is to insure equity. If you have a special situation that isn't covered here, I would be glad to talk with you about it.

Grading

The homeworks collectively count for 35% of your grade. The homeworks will be graded by the TA's. The TA's will initial the homeworks they grade, so you will know which one graded your paper. If you have a question about the technical content of your graded homework, you can ask either me or the TA's. If you have a question about the number of points you received for a problem, you should first ask the TA who graded it. If you and the TA cannot agree, then I will

resolve the disagreement.

Late Homeworks

Homework assignments are due on Friday. The solutions will be handed out on Monday at the end of class. The assignments can be submitted in class on Friday, or at my office (slipped under the door if I'm not there) any time before 6 PM. Any homework handed in by the 6 PM deadline on Friday will receive five bonus points. Homework handed in after 6 PM on Friday but **by the end** of class on Monday will be accepted without penalty but without bonus. **No homework will be accepted after the end of class on Monday.**

Assignments Missed Because of Illness

If you are excused from a homework assignment because of illness, that assignment will not be used in computing your homework average. In effect, you will be getting the average grade of your other assignments for the one missed.

Working Together on Homework Assignments

It is sometimes difficult to find the right balance here. I encourage you to discuss the problems with each other, and even to compare answers, because you can learn a great deal that way. On the other hand, it is essential that you each work through the problems in detail on your own. If you rely too heavily on your classmates for help with the homework, you will have difficulty with the exams, so it is in your own best interests to use good judgment about this.