Book Reviews

***Maple Computer Guide for Advanced Engineering Mathematics*, Erwin Kreyszig and Edward J Norminton, J.Wiley & Sons, Inc., 2001; ISBN 0-471-38668-5**

***Mathematica Computer Guide for Advanced Engineering Mathematics*, Erwin Kreyszig and Edward J Norminton, J.Wiley & Sons, Inc., 2001; ISBN 0-471-38669-3**

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Generations of senior engineering students will have found "Advanced Engineering Mathematics" (AEM) by Erwin Kreyszig on their reading list as a recommended textbook. It is now in its 8th edition, and, from the same publisher, there is available an accompanying "Computer Guide" for each of the two major Computer Algebra Systems (CAS), Maple and Mathematica. These guides, the subject of this review, serve two purposes. First, each can be used in a computer-supported course in advanced engineering mathematics, based on AEM. Secondly, each is an introduction to the use of a particular CAS, assuming that the reader is already sufficiently mathematically literate that he can cope straightaway with such topics as the solution of differential equations and vector calculus – both texts lead with a statement that familiarity with any CAS is not assumed, which I find a little hopeful! The guides, at about 300 pages each, are only a quarter of the length of the full textbook! So the pace is brisk, to say the least.

Maple and Mathematica are mature CAS and have ample tools to do the job. Although there are some slight points of difference in the contents – the Maple guide covers slightly more topics than the Mathematica guide - the main purpose of this review is to look at how the computer algebra support provided can enhance the teaching/learning of mathematics for senior engineering students. The guides are written using the Student version of Maple 6 and Mathematica version 4, respectively. Most of the examples, however, would run under earlier versions of the software.

There are seven sections of AEM which are also covered in the guides: Ordinary Differential Equations; Linear Algebra, Vector Calculus; Fourier Analysis and Partial Differential Equations; Complex Analysis; Numerical Methods; Optimization, Graphs; Probability and Statistics.

Each computer guide opens with a short introduction to the syntax of the relevant CAS. As the first chapter, which follows this introduction, is devoted to the relatively non-trivial topic of ordinary differential equations, the teacher will, as I indicated above, need to be assured that the student audience is capable of simultaneously tackling a new topic and using possibly unfamiliar software. Some might think this too much to expect.

The focus in the guides is, of course, rather different from that of the main textbook. The latter is very strong on developing the mathematics and the mathematical methods in the context of applications from physics. In the guides, however, the job is to show how a CAS can be used as an interactive symbolic calculator to produce answers to problems posed in standard mathematical form, and to provide further exercises for the student to gain confidence – note that solutions are given and there is plenty of cross-referencing with AEM. In the first chapter, the guide goes straight into finding the general solution of a simple first order ordinary differential equation (ODE):

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> ode:=diff(y(x), x)=3*y(x);
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$$ode := \frac{\partial}{\partial x} y(x) = 3y(x)$$

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> dsolve(ode);
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$$y(x) = \_CIe^{(3x)}$$

in Maple.

This example is followed by: (i) the particular solution of an initial value problem for the same ODE; (ii) a check that the general solution satisfies the ODE; (iii) a plot of the particular solution. Interspersed are some examples of incorrect syntax leading to error messages. I would like to have seen a plot of a family of integral curves of the ODE to give the student a clearer idea of what the general solution actually represents. Of course this is discussed in AEM, and to a certain extent is made up for by the next section on direction fields. For this one has to load the package DEtools for Maple or the standard add-on package Graphics'PlotField' for Mathematica. Other examples in this chapter are: a mixing problem; integrating factors; Bernoulli's equation; R-L circuit. Twenty problems are given at the end of the chapter for the student to try out, of which the last two demonstrate the use of a do-loop in carrying out Picard iteration. On the whole there is not much mention of methods of solution, so in particular, one isn't told whether the CAS regarded/solved the ODE as a separable equation or of first order linear type. Similarly, in the next chapter on linear ODEs of second and higher order, the software is used purely in blackbox mode – there is only a very brief passing mention of the characteristic equation for one example.

This second chapter contains mainly what one would expect: general solution; initial value problems; damped oscillations; nonhomogeneous equations with application to circuits; resonance. It is for this topic that one gets the first indication of the real payoff from having a CAS at one's fingertips: the immediate availability of solutions; the ability to change initial values and coefficients; a plotting facility. There are, however, a couple of examples that perhaps reveal the age of AEM: a discussion of the Wronskian; the Euler-Cauchy equation. I haven't felt a need to teach these topics for years!

In the third chapter, on systems of ODEs, there is scope for using linear algebra. In Maple one has to load the "linalg" package – the relatively new numerical linear algebra package "LinearAlgebra" is never invoked. To get the most out of this topic one also has to load the "plots" and "DEtools" packages at appropriate places. So quite early on, the student is required to have a knowledge of the resources available in these Maple packages. In Mathematica, the situation is slightly different, in that most of the relevant commands are already in the kernel. Of course one still has to know them! There is also a difference between the guides in this chapter in terms of content. The Maple guide covers the Van der Pol equation as an example of a non-linear system. This is absent from the Mathematica guide, as are further non-linear examples (eg Duffing equation) from the end-of-chapter problems.

Chapters 4 and 5 cover series solutions and Laplace transform methods, respectively. These topics are treated very much with the mathematics as the black-box, so there is a very strong need to have either AEM or another textbook at one's elbow. As before, there is much scope and good use of plotting facilities. There is also, in the Maple guide, the first example of a "Procedure". The procedure chosen generates Legendre polynomials from Rodrigues's formula – not perhaps the most efficient method, but at least it is simple. In the Mathematica guide the "Table" function is used to the same effect.

Chapters 6 through to 9 cover linear algebra and vector calculus. I do feel here that opportunities have been missed to fully exploit the excellent graphing facilities of both CAS. I was particularly disappointed at the paucity of 3d plots of functions of two variables, and the absence of any examples of contour plots or real-time rotation of surfaces.

In contrast, in chapters 10 and 11, there is excellent use of graphs to help the student get a feel for the mathematics and application of Fourier series. This includes convergence, discontinuities, the Gibbs phenomenon and the solution of the standard Partial Differential Equations with relevance in engineering.

It is not my intention to itemise all the good and bad points in these guides, but I would like to conclude by drawing attention to the shortest section of the guides, namely that on "Optimisation and Graphs". It is perhaps these topics which will be least familiar to some teachers, and it is here that the guides differ most significantly. Both guides deal, very briefly, with unconstrained optimisation (method of steepest descent) and constrained linear optimisation (simplex method of linear algebra). For the method of steepest descent, a relatively elaborate procedure (module) is described in the Maple (resp. Mathematica) guide. The Maple guide also covers a handful of examples under the chapter heading "Graphs and Combinatorial Optimisation". This requires the "networks" package, with examples of graphs, digraphs, incidence matrices, shortest spanning trees and flows in networks. These topics are omitted from the Mathematica guide, which is a pity because the tools are available in the standard add-on package "DiscreteMath". The brevity of the treatments in the guides does perhaps illustrate a current point of interest that optimisation tools are very underdeveloped in the latest versions of Maple and Mathematica.

In summary, I feel that these guides provide plenty of good examples to enhance the teaching of mathematics to senior engineering students, provided that the students already have had an introduction to the use of a CAS. There are some things I would wish otherwise, as mentioned above, but they are all things that a good teacher would and could overcome quite easily from his own experience and knowledge.

Linear Algebra by Roger Baker
Rinton Press Inc

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The Preface explains that "This book is designed for a one-semester first course in linear algebra…that an average hard-working student, not necessarily a math major, could read from cover to cover during a semester." Any course on linear algebra has a choice on the order of material. Do you solve linear equations before introducing vector space terminology? At what stage do you introduce matrices? When, if at all, do you describe the geometry of real 3-dimensional space?

In this book, the chapters are as follows:

1. Euclidean space
2. Linear systems and matrices
3. Linear independence. Subspaces
4. Linear mappings. Matrix algebra
5. Determinants
6. Eigenvalues and eigenvectors
7. Symmetric matrices and quadratic forms
8. Vector spaces

The book reads very well: the material has been carefully honed through the course having been given many times. Is it suitable for a first-year course at a British university? There is a bow to abstraction only in the last chapter. The use of the word "permutation" is unfortunate, since it here means an arrangement of {1,…,n} rather than the more usual idea of a bijection of the set with itself.

Overall it is an excellent book which would do very well for non-mathematics majors but less well for mathematics majors.

Duelling Idiots and Other Probability Puzzlers, P. J. Nahin
ISBN 0691009791, Princeton University Press

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I should begin by being upfront and stating that I volunteered to write this review. About a year ago I acquired this book as a freebie in return for some refereeing for Princeton University Press. I was so impressed that I ran out and bought three copies for mathematically-inclined friends. I'm writing this review, in part, as an excuse to put forward a personal perspective on my teaching resource needs: As a university-level teacher I am not looking for another Visual Basic package that implements a Runge-Kutta formula with $\triangle t = 0.1$ or plots rational quadratics with asymptotes labelled or fits a least-squares straight line through some random data, nor am I waiting expectantly for the next introductory text on calculus, linear algebra, numerical analysis or statistics. What I *can* use is more snappy examples of mathematical problems that:

- can be set up in a few sentences
- are easily motivated by appealing to students' experiences
- start off easy, but naturally lead into more challenging tasks that can only be tackled computationally
- show how mathematics can bring clarity to the description of a problem and insight into its answer

Nahin is a Professor of Electrical Engineering at the University of New Hampshire. He has written a number of popular science books, including *An Imaginary Tale: The Story of the Square Root of Minus One*, Princeton University Press, 1998. He has been teaching probability theory to EE undergraduates for 25 years and this book evolved from his practice of setting extra, optional, assignments for students who wish to boost their grades. His preface mentions that two spells in industry brought home to him that elementary probability is a key engineering tool. This contrasts with his experiences in the 1960s as an undergraduate student at Stanford and masters student at Caltech, where he was never exposed
to the topic.

The book is based around 20 problems. I will mention two examples. Problem 2, *When Idiots Duel*, begins with a scenario where two adversaries, A and B, take turns to shoot at each other with a single, accurate, gun that has a single bullet in one of the six barrels. The barrel is re-spun between shots. They keep going until the bullet is fired. A goes first. What is the probability that A will survive. What is the average number of shots taken in such a duel? Nahin shows how to calculate the answers. The first question involves a simple geometric series, and the second a slightly more general, but equally tractable, infinite sum:

$$S = 1 + 2\left(\frac{5}{6}\right)^2 + 3\left(\frac{5}{6}\right)^3 + 4\left(\frac{5}{6}\right)^4 + \cdots$$

(I plan to ask my first-year algebra class to find that *S*.) He then gives the results of a MATLAB simulation to approximate the distribution of the number of trigger pulls per duel. The assignment for the reader is: what happens if we change the rules so that A has one shot, then B has two shots, then A has three shots and so on? (Do you think A is still more likely to survive than B?)

Who pays for the Coffee? is problem 9. Here N workmates send one of their number out to Starbucks. Rather than paying individually, they decide to flip one coin each simultaneously. If all but one coin show the same face, then the odd coin's owner pays for the coffees. If there is not a single odd face, then they re-flip and so on. When is the flipping end reached, on average? After some basic combinatorics, Nahin shows that the answer again involves a generalised geometric series like *S* above. He also gives a MATLAB simulation of the distribution of the flip number. The assignment is to answer the question in the case where $N - 1$ of the coins are fair but one is biased - it shows heads with probability $0 < q < 1$.

As these two examples suggest, a typical problem begins with a simple puzzle that is solved with elementary algebra and calculus and perhaps backed up by simulation. Then the reader is invited to tackle a more general version. This may involve further analysis, simulation, or both. Solutions are provided and at least one short MATLAB code accompanies each problem. I commend the way that analysis and simulation are given equal weight, and the way that the MATLAB programs are displayed in full, big-fonted listings, rather than being ashamedly tucked away on a disk or a website. A very accessible 20 page appendix on random number generators is also included. The author's views on simulation are stated in the preface (page xiii).

Indeed, a major pedagogical theme of the book is the following:

Part 1: No matter how smart you are, there will always be a problem harder than the one you can solve analytically.
Part 2: If you know how to use a computer application like MATLAB, you may still be able to solve that "too hard" problem by simulation.

The programs in the book are designed to be easy to follow. They meet this aim, thanks in part to ample use of comments, but they could be dramatically improved. Most of MATLAB's built-in functions, including **`sum`**, **`mean`** and **`std`** for computing sums, means and standard deviations, plus its powerful arraywise arithmetic, are overlooked in favour of scalar-based **`for`** loops. For this type of expository work it is clearly best to go for simplicity and transparency. However, in my experience a vectorised MATLAB code is usually the clearest. A one- liner with **`sum`** is less daunting than a Stone Age **`for`** loop that uses a temporary variable to grind out a running total. Equally importantly, for the type of Monte Carlo simulations that abound in this book, vectorisation can improve execution speeds by several orders of magnitude, making the difference between enjoyable interactive experimentation and frustrating overnight delays. To be fair, Nahin, does acknowledge the naivety of the codes; from the preface (page xviii)

> . . . which allows some very nifty code to be written. I will, in fact, use very little of that power in this book . . .

and he gives a reference to a more advanced MATLAB text. Although far from exemplary, these MATLAB codes are at least accurate and accessible. Princeton University Press did not make the files downloadable, but an interested reader, Robert Astalos, subsequently corrected matters, with Nahin's permission. The required URL is

http://quasar.phys.vt.edu/~astalos/index.html

The mathematical treatment is always informal. Basic axioms of probability theory are nowhere in sight, nor is a formal definition of an expected value. However, Nahin still manages to touch on some advanced topics, such as the Critical Path Method, Brownian motion and mean hitting times for Markov Chains; and he gets across some subtle points. Who could resist the following passage from Problem 14, *The Random Radio?* (Here, *A*, *B* and *C* are independent, uniform (0; 1).)

> *This assertion usually astonishes students (and surprised me), who argue that since B and C are independent, then why would dividing both by the same value (A) suddenly make the ratios dependent? It does, and you are about to prove it. Here's your assignment . . .*

Of course, the examples here can be used in probability classes. Moreover, by following Nahin's informal style it is possible to set them up quickly from first principles and slip them into courses on calculus, algebra or scientific programming. They also offer a wealth of topics for undergraduate projects. Those duelling idiots are fighting over a goldmine.

Addendum... After being contacted by the reviewer, Princeton University Press have made the MATLAB files downloadable from the book's website at
http://pup.princeton.edu/titles/6914.html