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# BOOK REVIEWS

**Analytical Mechanics**, by A. Fasano and S. Marmi, Oxford, Oxford University Press, 2007, xiii + 772 pp., £49.95 (hardback), ISBN 019850802. Scope: handbook. Level: graduate students.

The title *Analytical Mechanics* may initially strike one as a little old-fashioned (one recalls Whittaker's 1904 treatise) in a subject that has come to be dominated by geometric and topological methods. However, whilst the text doesn't include the statutory short course on differential geometry and it isn't presented in the abstract language of bundles and connections, it is necessarily geometrical. Perhaps the word 'analytical' is a historical or even a cultural reference as well as carrying the suggestion that a course in undergraduate calculus is a sufficient preparation for reading. It is a translation of the Italian text *Meccanica Analitica* (2002) and the translator is to be congratulated on her style which flows naturally across the native ear.

Consistent with the authors' stated aim to bridge the gap between elementary and advanced courses the book cuts no corners and covers a wider range of subjects than one might expect. It *is*, it has to be said, a very long book in consequence though this is partly due, in addition, to the generous provision of exercises and *additional solved problems*. The authors have gone the extra mile!

The theme is developed in a traditional manner, the path leading from the geometry of kinematics through the Newtonian view of dynamics to the Lagrangian formulation (with a thorough review of central force and rigid body motions) to the Hamiltonian as far as a very worthwhile treatment (70 pp) of Hamilton–Jacobi theory and integrability. Another substantial chapter deals with the non-integrable end of the stick including Birkhoff forms and the KAM theorem. Three reasonably substantial chapters then deal with ergodic theory and chaos, the kinetic aspects of statistical mechanics and then the Gibbs ensemble. There is a final chapter on the Lagrangian treatment of continua which is, I suppose, philosophically in the right place but it feels a little like an afterthought. Or the beginning of another book. The volume concludes with eight appendices on material which is genuinely supportive of the main body of the text.

There is a wealth of unexpected substance to this text. The chapters do not, as so often is the case, pull out just as life is getting interesting and, supplemented by some other more abstract monograph, it would be an excellent handbook to a graduate course on classical dynamics. Bravo!

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**Applied Computational Materials Modeling. Theory, Simulation and Experiment**, by G. Bozzolo, R.D. Noebe and P.B. Abel, Berlin, Springer, 2007, xvi + 491 pp., £77.00 (hardback), ISBN 978 0 387 23117 4. Scope: handbook. Level: researchers.

My initial excitement at receiving this book to review soon turned to disappointment when I realised, upon opening it, that it is in fact a collection of articles edited by the listed three authors. The usefulness of such a book is, in my experience, largely dependent upon the selection of topics, authors and editing.

In this case, it quickly became apparent that the topics, far from covering all (or even a modest spread) of materials modelling, are instead very narrowly focused on the study of metallic alloys. Within this narrow range, the authors do a reasonably thorough job, covering *ab initio* calculations, atomistic molecular dynamics and Monte Carlo simulations, finite element modelling and quasi-continuum approaches. The basic theory, a few computational details, and many example results are presented, often with a detailed interpretation and comparison to experiment. There is a systematic progression of topics through the book, starting with primarily *ab initio* modelling (including application to structures, growth and alloy phase diagrams) and ending with multi-scale modelling of fracture, deformation and microstructure.

One failing of this book is that there is a lot of needless repetition of background theory and computational methodology. For example, Density Functional Theory, the BFS method and CALPHAD are all explained a number of times in different chapters. I would have expected the editors to do more here to increase the integration of the separate articles. As it is, each article is more like a stand-alone mini-review of

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the authors' work, rather than an unbiased treatment of a given topic. This is irritating, and some of the chapters are particularly partisan. In principle, a set of stand-alone articles can make a useful reference work if accompanied by a thorough index, but sadly, this is not the case here. However, each chapter does have an extensive set of references (not all to the work of the primary authors) and setting author bias aside, can serve as a good introduction to a particular topic.

In summary, this is an interesting book that covers a wide range of topics that are narrowly focused upon the modelling of metallic alloys. Each chapter is a good stand-alone article but the book as a whole is let down by the editing, and it does not feel like a cohesive entity.

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**Aurora – Observing and Recording Nature's Spectacular Light Show, in the Patrick Moore's Practical Astronomy Series**, by N. Bone, Berlin, Springer, 2007, x + 190 pp., £20.50 (paperback), ISBN 9780387360522. Scope: monograph. Level: general scientific reader.

As we come out of the present sunspot minimum and begin sunspot cycle 24, it is timely to consider how best to observe the spectacle of the aurora borealis (or australis in the Southern hemisphere) as these visions return to high latitudes, below Arctic or Antarctic regions. Although Neil Bone shows in this book some spectacular aurora from the north and the south of the UK, taken during a high activity period in a previous sunspot cycle, UK readers are not likely to see aurora except in Scotland, unless fortunate to visit northern Norway in winter. (Tromsø University hosts an international facility for radar probing of geomagnetic effects in the ionosphere, but the UK does have a useful website [AuroraWatch from Lancaster University] that monitors geomagnetic activity and hence gives some advance notice of conditions that may provide good aurora sightings here.)

The photographs are, as one would expect, an important element of this text but the many graphs and other figures help to illuminate this complex subject. There appears to be an error in the figure that provides the energy levels for atomic oxygen, the source of red and green emission wavelengths, where the labels and lifetimes of the quantum levels have been transposed. However, this small book presents in greater depth a very readable account of the origins of the aurora with a concise explanation of the solar physics that drives sunspot activity and the related geomagnetic activity at the Earth. Those of us who work with laboratory plasmas can produce small scale illustrations of light emission from gas mixtures excited by energetic electrons, but it is the atmospheric scale displays that provide the most impressive shows. It is not surprising that these have inspired myths and superstitions from early times, nor that we are still unravelling details of the mechanisms that connect aurora with solar magnetism.

In general, plasma physics is not a subject that is tackled by amateur astronomers, but I recommend anyone who is curious about the origins of the aurora to dip into this monograph and be encouraged to look out for this free light show that is driven by the solar wind from solar corona disturbances. In addition, amateur astronomers should enjoy the chapter about aurora on other planets, although observations require Space-based platforms, such as the images from the Hubble Space Telescope of Jupiter's aurora.

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**Differential Geometry and Lie Groups for Physicists**, by M. Fecko, Cambridge, Cambridge University Press, 2006, xv + 697 pp., £45.00 (hardback), ISBN 0521845076. Scope: survey. Level: students and researchers.

A number of assumptions are implied by a title such as this. The first is apparently unarguable: that there is a deep, even structural, affinity between physics and geometry; the second is a part of the modern didactic tradition: that physicists need a treatment of differential geometry somehow suited to their own purposes, a distillation of the good bits from the pure canon; the third: that the particular book in question fills a gap in the market.

From the point of view of content Marián Fecko's book is pretty traditional: everything is smooth; the physics targeted is Hamiltonian mechanics, gauge theory and general relativity; surveys of the abstract material precede the applied. There are occasional nods to more *avant garde* topics such as category theory but their roles are not deeply explored.

From the point of view of presentation the book has a lot going for it. It is written in a pedagogically discursive, conversational style with numerous workable examples and exercises distributed through the text. There are summaries of notations and results which will make it a very useful and student friendly text. Which students? From the UK perspective a student undertaking a level 4 (level 5 in Scotland) or MSc course in theoretical physics would find this book well-pitched to his or her needs.

Rather than cover the material of the whole book let me discuss one chapter in some more detail. Chapter 14 deals with 'Hamiltonian mechanics and symplectic manifolds'. Hamilton's equations on $\mathbb{R}^n$ are interpreted as a vector field motivating the introduction of the Poisson bracket on functions on $\mathbb{R}^n$ in a coordinate free way. The abstract idea of a symplectic 2-form is introduced and the Lie algebra of Hamiltonian vector fields. Some details are left to be confirmed by the reader and the physical interpretation of the abstract quantities are kept in view. Transformation theory is then discussed and generating functionals given a clear treatment in terms of exterior differential algebra. General integral invariants are presented and their specific implications for geometry e.g. area conservation. The relations between symmetry and conservation laws is neatly presented using the Lie theory from earlier in the text and then the crucially important moment map with illuminating examples and plenty of reader activities. The coadjoint action as a machine for generating symplectic manifolds with nice structure is given. The chapter culminates in a nice treatment of symplectic reduction, followed by a summary of results and notation. Overall a presentation which tells the story well.

I guess this genre of text does raise the question of tradition in teaching and how far one should try to push the envelope. There are large and important areas not touched upon at all: nowadays discrete systems (specifically integrable) are becoming increasingly important and alongside them the machinery of discrete differential geometry. Even if one doesn't want to go that far there must be an argument for including treatments of simple discrete systems and discretisation of continua. Then again category theory is becoming increasingly user friendly and increasingly important in physics so there is new ground to be broken there too. There is too a bias towards the 'big' theories of physics, if not 'theories of everything' then those which claim to grapple with the fundamental nature of the world. But a theory is a model and we know from modern nonlinear dynamics that models are not generically structurally stable or topologically classifiable. Why is fundamental physics immune from this critique? Shouldn't a book on geometry and physics include material on deformation theory and structural stability?

Perhaps we should ask whether the traditional view of the corpus of differential geometry might not be prejudicing our view of fundamental physics and blinkering our students' eyes to more general possibilities.

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**Flow Cytometry with Plant Cells**, edited by J. Doležel, J. Greilhuber and J. Suda, New York, Wiley-VCH, 2007, xxiv + 454 pp., £100.00 (hardback), ISBN 978 3 527 31487 4. Scope: monograph. Level: general reader, professional and specialist.

Why should a book on the detection and characterisation of plant cells appeal to physicists? There could be many answers to this question, but in this era of multidisciplinary research, the contents of this book appeals to all scientists, and the requirements of life scientists to have rapid methods for sorting cells and the structures within cells is increasing. For those wishing to learn about some of the technical limitations in any form of flow cytometry applied to plant or mammalian cells, this book serves as a useful introduction and it contains most of the definitive references to the subject. The three editors are to be congratulated on putting together 18 chapters contributed by leading experts in a way that serves both to introduce the topic to the newcomers, and to provide snapshots of the state-of-the-art for the plant scientist.

The first chapters give an overview of flow cytometry and narrow this down to the specific issues of dealing with plant cells. There follows specialist chapters dealing with the genomics, DNA composition, pathological agents, protoplasts, chloroplasts and related topics. Most of these chapters can be read with understanding by the physicist, engineer or chemist, and in many cases the contributors have explained the basics of the relevant plant science for the non-expert. Phytoplankton is dealt with in a most readable section, with particular appeal to the reviewer who once collected plankton from a home-made net and was intrigued by the variation and diversity. Cell cycle analysis is also given a complete chapter as is chromosome analysis and sorting. Gene expression and the development of a DNA flow cytometry database represent the final chapters.

This reviewer is a physicist-turned-engineer who has developed a fascination with the issues facing life scientists, and is, in turn, hoping to find solutions to detect and identify particles in aqueous fluids. There are big challenges, ranging from detecting subtle differences in cells, to detecting and identifying the inner components of cells, down to nanometre sizes. I sincerely hope that physicists or engineers will take a look at this subject, and using some of the recent advances in optoelectronics, find ways to help their life scientist colleagues. I found the book to provide a lot of valuable insight and to direct me to the appropriate research groups. It is a nice, compact and well-produced volume as one expects from this publisher.

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**How Mathematics Happened. The First 50,000 Years**, by P.S. Rudman, New York, Prometheus Books, 2007, 314 pp., £18.99 (hardback), ISBN 9781591024774. Scope: discussion. Level: scholars.



Peter Rudman's book *How Mathematics Happened* is a fascinating account of the origin and use of numbers from the earliest development of counting methods, perhaps seven millennia before the birth of Christ, to the pinnacle of classical mathematics in third century BC Greece. There are so many fascinating discussions and investigations in this book that it is quite difficult to know where to start. I do not wish to steal Rudman's thunder by cherry picking too many of the delightful areas which the text visits, however I cannot resist some 'dipping and delving'. One element of the book which is somewhat unusual is the introduction of many exercises to keep the reader engaged with the development of the subjects in the text. Some of these are quite challenging, however if one only gives them cursory attention, the value of this book is only slightly diminished because it can be read as a history of the subject and not necessarily a primer for learning ancient mathematical methods. At first sight one might question how one could obtain information on the methods which were used by primitive people well before any historical records existed. However, this is where early archaeology and anthropology come to the author's aid for unusual counting methods were documented by anthropologists, in the nineteenth century, who were investigating isolated communities which had not been exposed to modern European civilisation and seemed to have survived with their culture intact for many millennia. One general point I would like to make is raised in a recent article by J.D. Jackson [*American Journal of Physics* 76 (2008), pp. 704–719] entitled 'Examples of the zeroth theorem of the history of science' in which he quotes M.V. Berry's remark that 'Nothing is ever discovered for the first time'. This should be born in mind for it may well put into perspective that which follows.

Rudman discusses many of the varied counting systems which have evolved and their advantages and disadvantages. He points out that the early form of finger counting was soon replaced with the use of pebbles when flocks contained more than ten sheep or cattle! The first written records of counting are found in Egyptian papyri in the fourth millennium BC which are reasonably easy to read once one has learnt the various symbols because the Egyptians use base ten, the system used the world over. Their system is additive and so is quite easy to master. The Sumerian culture which developed along the Tigris and Euphrates around the same time as the Egyptian civilisation used base 60 which makes learning the 59 different symbols somewhat of a challenge for us today. However, they were the first to adopt a 'replacement system' where the same symbol can imply different values depending upon where it is placed in a line or column. We use this system where a '1' in the units column is worth only one tenth of a '1' in the tens position etc. It is interesting to note that, seemingly independently, the Mayans in Central America developed a very similar counting system to that of the Sumerians but using base 20 rather than base 60 some 4000 years later. Rudman explores at some length the passion that the Maya had for quantifying their world and notes that they knew the period of the Moon to one part in 30,000. Before leaving systems of counting it should be mentioned that the decimal system came into Europe via translations into Latin of Arabic texts, however this was not the origin of the system for it was actually developed in India a thousand years earlier; Arabic mathematicians acting as the vector between India and Europe.

The first land surveying techniques seem also to have been developed in Egypt through a need to collect the appropriate taxes. In order that the tax paid by individual farmers should reflect their earning capacity the land inundated by the annual Nile floods which brought the silt which enriched the soil had to be estimated annually. And it appears that ropes were used to measure the lengths and widths of pieces of land, much as standard chains were used from the late sixteenth century in Europe. The area of the land could then be found from multiplication firstly using the tedious method of successive addition but subsequently by using a subtle 'binary algorithm' which seems from the Rhind Papyrus to be the first use of binary arithmetic. Egyptian mathematicians explored the finding of volumes of simple solids and also evaluating simple whole number fractions.

It is fascinating to learn that the Babylonians were familiar with what we know as Pythagoras's theorem some 1500 years before his birth. Here the analysis of the cuneiform tablet known as 'Plimpton 322' after being assumed to be just another 'bill of sale' is quite amazing and revolutionised our understanding of the significance of the mathematicians of the ancient cultures of the Middle East. Although these cultures made very significant advances in solving quadratic equations they achieved these results without the use of our algebraic notation which was only developed in Europe some 400 years ago. As they had not developed symbolic algebra they had to use somewhat cumbersome sentences in what is termed rhetorical algebra. And so with the use of line diagrams and rhetorical algebra they developed their outstanding mathematics. They were hampered also by not having access to anything but whole number fractions for the decimal point was not introduced by Indian mathematicians until around the time of the birth of Christ.

The work of the Sumerian and Egyptian mathematicians is poorly known to us today because it has been replaced by more modern notation and simpler methods. However, this is not the case with Greek mathematics for we are much more familiar with this material for most of the geometry we use today has its origin in Euclid's *Elements* with which every school child was familiar until moderately recently!! And I suppose it is only right and proper that this fascinating text should complete its historical journey with a discussion of the amazing proof by Hippasus that then square root of 2 is irrational. This breathtaking proof bridges the 2000 year divide from classical mathematics to modern abstract ways of thinking and demonstrates the immense power of abstract thought that mankind has exhibited throughout history.

In summary, I found Peter Rudman's book very accessible and I believe it should be of interest to all who have a love of their cultural roots and particularly wish to know more of the origin of numbers, their early usage and the dawn of classical mathematics. Until reading this book I had only the sketchiest knowledge of this subject which I had picked up largely by accident. Rudman's book is thorough and well researched and contains fascinating observations on how we have arrived at our current numbering systems and where so many of the uses of numbers which we take for granted have originated.

(Had I got my act together and completed this review before Christmas I could have ended it with the comment that this book would make a truly excellent Christmas present!)

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**Introduction to Elementary Particle Physics**, by A. Bettini, Cambridge, Cambridge University Press, 2008, xiv + 431 pp., £35.00 (hardback), ISBN 978 0 521 88021 3. Scope: textbook. Level: postgraduate and advanced undergraduate.

If the Higgs boson is found this year *Elementary Particle Physics* will get a much-needed shot in the arm and this book will turn out to have been published at a very opportune time. Alessandro Bettini is, amongst his other positions, Director of the Gran Sasso National Laboratory in Italy, and his book provides (postgraduate and advanced undergraduate) students with an admirably clear account of the Standard Model. Its general aim is to describe this model in sufficient depth to give a good understanding of it, while not developing the full intricacies of non-abelian gauge theories with spontaneous symmetry breakdown. This aim is well achieved, as much as anything else by the author's groundedness in his (correct) insistence that this subject, like all subjects in physics, is an experimental as well as a theoretical one. Much emphasis is placed on the importance of numbers and the details of the experiments, while the theoretical picture is still kept in sight.

The coverage is, in a sense, predictable and standard – hadrons, leptons, quarks, QCD, weak interactions – but the treatment of these topics is permeated by constant reminders of experimental procedures and order-of-magnitude calculations. The prose is consistently fluent and interesting, the author's knowledge up-to-date and detailed and the explanations admirably lucid. More difficult theoretical topics are by no means avoided, and a student who reads this book concientiously will finish up with an understanding of, for example, what properties of quarks are measurable and what unmeasurable, of the inadequacies of the 'static' quark model of the 1960s and some appreciation of the QCD vacuum and quark confinement. The chapters on weak interactions cover Cabibbo mixing and the CKM matrix, the Glashow–Iliopoulos–Maiani mechanism, weak neutral currents, the K and B mesons and CP violation; and the penultimate chapter gives a nice survey of the Standard Model – the electroweak interaction, the UA1 experiment and the discovery of W and Z, precision tests at LEP and the search for the Higgs boson. Many of these topics are difficult but the author consistently finds a clear way through and the ultimate feeling is that this is not a 'heavy' book, though it is packed with information. It also contains lots of problems and exercises, ranging from 'Find the Dalitz plot zeros for the $3\pi^0$ states with $J^P = 0^-, 1^-$ and $1^+$', to 'Estimate the energy of a Boeing 747 at cruising speed and compare it with the energy released in mosquito–antimosquito annihilation', and 'What would the universe be like if protons were heavier than neutrons?'.

The final chapter goes beyond the Standard Model. It is a shame that the author does not state explicitly that this model, although 'correct', is probably not fundamental, since it leaves as free parameters so many quantities such as masses, mixing angles and the number of quark and lepton generations; surely in an ultimate theory these quantities should be explained. The chapter is devoted instead almost entirely to neutrino oscillations and associated subjects. There is a final couple of pages on speculative matters such as supersymmetry, dark matter, dark energy and the gravitational interaction. Despite my caveat above it is nice to find a book free of the wilder speculations of Theories of Everything, superstrings and quantum gravity. Students who want to study these esoteric matters would be well advised to digest this excellent book first.

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**Introduction to Quantum Theory**, by H. Paul, Cambridge, Cambridge University Press, 2008, viii + 176 pp., £25.00 (hardback) ISBN 9780521876933 (also available in eBook format, US$40.00, ISBN 9780511405952). Scope: supplementary text. Level: teachers, final year or graduate students.

In spite of the title, this is not an 'introduction' in the usual sense. However, Harry Paul provides a valuable 'supplementary' text that will be particularly appreciated by University scholars, teachers, final year or graduate university students who already have knowledge of the nitty-gritty of quantum theory. Readers who are familiar with Harry Paul's earlier book *Introduction to Quantum Optics* will appreciate the writer's ability to condense and distil complex ideas.

Even having read endless accounts of the origins and methodology of quantum theory, the reader is likely to find fresh insights given by Paul. Here one finds 10 chapters with each illuminating difficult points ranging from quantum states, through correlations, philosophy, appearance of quantum effects in macroscopic phenomena to end with an account of quantum computing. There are so many gems in this short book that this review cannot do justice. Few of us probably realised that Newton required 'hidden variables' well before the term was invented. By drawing attention to the wave interference of atoms being encoded by internal states, perhaps Paul hints that all interference might be provided by internal states. The full complexity of the mathematical formalisms is bypassed by Paul telling the reader his account of the mathematics is simply a reminder. There is an account, unusual for introductory texts, of the Wigner function as a mathematical demonstration of how variables like momentum and position can have the correct complementary probabilities. The same chapter also contains an excellent overview of parametric down conversion producing entangled pairs of photons. The Star Trek myth of teleportation is dealt with concisely showing it is the 'state' not the substance that is teleported. The chapter on correlations is particularly welcome to this reviewer who regards eigen measurements as the outcome of stationary correlations. Paul uses correlations to assist the understanding of both entangled quantum states and squeezed states in optics where phase and amplitude fluctuations can be correlated to enhance the signal-to-noise ratio in certain types of communications. The final chapter is an excellent précis of the why, how and when of quantum computing. Even though there is a bewildering choice of books on quantum theory, this is a most welcome and stimulating addition.

In such a short book there will inevitably be disappointments. For some, the chapter on philosophy will have concentrated too much on the Einstein–Podolsky–Rosen paradox. More also could have been usefully said in the book about the photon, but of course one can read Paul's previous book on quantum optics.

The potential reader may note that Cambridge University Press are offering this as an e-book. A particular advantage here is the ability to search electronically.

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**Plasmonics: Fundamentals and Applications**, by S.A. Maier, Berlin, Springer, 2007, xxv + 223 pp., £59.00 (hardback), ISBN10 0 387 33150 6, ISBN13 978 0387 33150 8. Scope: research monograph. Level: graduate students and researchers.

Plasmonics is a research field that has grown dramatically in importance in the last ten years or so. The study of plasmons in itself is not new, with origins going back about 100 years, but the new interest is inspired by the realisation that plasmonics can have important applications in the field of nanophototonics, which 'explores how electromagnetic fields can be confined over dimensions on the order of or smaller than the wavelength', as Maier puts it in his preface.

The turning point that defines the new era is widely accepted to be a landmark paper from 1998 which demonstrated enhanced transmission through an array of sub-wavelength holes. (Ebbeson et al., *Nature* 931, p. 667.) Since then, there has been an explosion of interest in the field, which makes Maier's work a very timely and welcome addition to any bookshelf.

In order to understand plasmonics, it is important to realise that there are two different types of plasmons: bulk plasmons and surface plasmons. The former are covered in most solid state physics texts (e.g. Kittel), but it is the latter that are of interest here. Surface plasmon polaritons and localised surface plasmons have been studied for many years, and a wonderful review of the subject as it stood in 1988 can be found in Hans Raether's classic text *Surface Plasmons* (Springer). Unfortunately, Raether's monograph was published posthumously, and is now out of print, and so it is left to the new generation to take the field forward. In this respect, Stefan Maier has done an excellent job.

The relatively short length of the text makes it friendly and appealing, without loss of depth. The book is divided into two parts. Part I deals with the fundamentals of plasmonics, while Part II covers the applications. The subject material is well organised, and clearly presented throughout, with abundant references to the primary literature. Some of the material in Part I is sufficiently well explained as to be accessible to final year undergraduates. Indeed, any undergraduate student doing a final year project on plasmonics will undoubtedly find this text extremely helpful. Furthermore, lecturers will also find it useful, since it is reasonably standard to include the basic physics of plasmons in final year undergraduate courses, and Maier's text gives a clear account of the new developments in the subject. Inevitably, some of the material in Part II will date fairly quickly, but since the main emphasis is on explaining the basic principles, I expect that the text will still be useful even when the state of the art in the research has moved on.

In short, Stefan Maier's text is very well written and fills a real gap in the market. I expect that it will become a classic, just as Raether's text did, but in Maier's case we can also look forward to new editions as the subject develops. I find it difficult to add to Bill Barnes' assessment in his foreword: ' ... we have been acutely aware of the need for a more up-to-date introduction and overview of the field at a glance. Now we have it – thank you Stefan'.

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**Quantum Mechanics for Scientist and Engineers**, by D.A.B. Miller, Cambridge, Cambridge University Press, 2008, 574 pp., £42.99 (hardback), ISBN 9780521897839. Scope: course book. Level: general reader.

David Miller is a distinguished Professor who is the course coordinator for Applied Quantum Mechanics I and II at Stanford University. He has devised a truly remarkable 'course book' that looks set to become a standard text. He builds on his own experiences and those of his co-workers in a lifetime of work in those areas of quantum mechanics that underlie key technologies of optics, semiconductors and quantum information. The book sets new standards of presentation and clarity with impressive electronic material made available through the Cambridge University Press (CUP) website. Here any reader can find worked solutions of selected problems, over 1100 'viewgraphs' for lectures along with animations such as vibration states of molecules and transmission of quantum waves through barriers. Under conditions of tight security, bona fide college lecturers may access from CUP the solutions to all the problems in the book with detailed workings and some Mathcad work sheets along with suggested examination questions.

Miller gives a clear account of non-relativistic quantum mechanics and shows how to apply this theory to realistic problems. The book is thorough and well constructed covering applications of quantum theory in electronic and optical devices and also some more advanced quantum mechanics used in lasers and quantum computing. Most of the requisite mathematics is usefully detailed in a series of appendices preventing it interfering with the physics in each chapter. The book can be particularly recommended for University lecturers, graduate students and undergraduates undertaking courses in these areas. All will be able to pick and choose their selected topics at appropriate levels from an abundance of written and electronic material.

Although Professor Miller has a final chapter recognising the difficulties of the interpretation of quantum theory, do not expect to find a novel answer to these difficulties. Miller takes the view that traditional non-relativistic quantum mechanics really works even if difficulties in what it all means remain.

This book reflects the immense labour required by University lecturers to create such textbooks. It is sad to observe that, in the UK, Research Assessment Exercises do not reward sufficiently this form of scholarship even if it forms a bedrock for future research. As an envoi, consider the first sentence on the back cover: 'If you need a book that relates the core principles of quantum mechanics to modern applications in engineering, physics, and nanotechnology, this is it'.

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**Spectral Methods for Time Dependent Problems**, by J.S. Hesthaven, S. Gottlieb and D. Gottlieb, Cambridge, Cambridge University Press, 2007, ix + 273 pp., £40.00 (hardback), ISBN 0521792118. Scope: textbook. Level: students and researchers.

This is yet another addition to the growing list of books on spectral methods. The authors are well known and distinguished experts in this field having published numerous research papers on the topics covered in the book. The main purpose of the book is to bring together various threads needed to understand the use of spectral methods for time-dependent problems. Indeed, in the introduction the authors claim that the book 'is distinguished by its exclusive treatment of time-dependent problems' and most of the focus is on partial differential equations with time and one space dimension. The book is aimed at graduate students and there has been a judicious choice of material in this respect.



Compared to other texts, the range of topics covered and the size of the book (273 pages) is just about right and not too daunting for the beginner. The book contains 12 chapters and two appendices. The earlier chapters contain mostly standard topics introducing spectral methods and its advantages as compared to high-order finite-difference methods. There is a concise coverage of approximation theory for continuous and discrete Fourier expansions and applications of Fourier spectral methods for the solution of partial differential equations. Chapter 3 includes a nice discussion of filters and how they can be used for stabilisation. This is followed by a discussion of the classical results for orthogonal polynomials (Jacobi, Legendre, Chebychev and Ultraspherical polynomials), and continuous and discrete polynomial expansions. The discussion of Runge's phenomenon and the link with electrostatics is excellent and not typically covered in other texts. I liked the coverage of Gibbs phenomenon and the approximation theory for filters and how Gibbs phenomenon can be resolved. Chapter 9 considers time integration schemes and the material is fairly standard but the exposition here is rushed and lacking the clarity that one might have expected after reading the earlier chapters. Finally the book finishes with a good discussion of computational aspects, including the FFT, accurate computation of collocation matrices, domain mappings, and the use of spectral methods on general grids.

Whilst a lot of the material is standard and recycled to suit the scope of the current text, nevertheless the book does include new material on filtering, discontinuous galerkin methods, the Gibbs phenomenon, and spectral methods on arbitrary grids.

There are a number of positive comments one could make. The book is eminently readable and the theoretical aspects have been kept to a manageable level. This will widen its appeal to non-mathematicians interested in learning about spectral methods but without the rigorous mathematical training needed to digest the important and subtle mathematical points. Indeed many other similar texts are either too basic or have too much emphasis on theorem-proof to be readily accessible. The authors have attempted to keep the theorem-proof side to an absolute minimum and this aids readability. The book is reasonably self-contained except when covering more advanced topics. The text contains a number of interesting examples illustrating various aspects of the theoretical results. This is meant to be a monograph so there are no exercises for the reader to try out although there are a number of examples covered which could be used as test cases for developing codes.

The book does attempt to introduce some recent developments, but the scope is such that experts will find that there is just enough discussion to whet one's appetite before the chapters promptly come to an abrupt end with a list of citations. There is then no further discussion of the topic in question. This is probably the most frustrating aspect of the book.

One also gets the impression that the individual chapters form a set of concise but well prepared lecture notes. There is not much in the way of background or motivation leading to the important points. The main points are dealt with quickly and without too much distraction. This is not really the book to get an overarching view of the subject. Rather the reader is told that these are the important facts and if you want to know more look at the research papers or consult other texts for more information.

Readers following the book will certainly be able to formulate the discrete equations for their problems using spectral methods, at least for one space dimensions. However, a distinct omission from the material is any information on how to solve these discrete equations. The efficient solution of the linear and nonlinear discrete equations arising from the problem formulation is an important aspect of using spectral methods and this is a topic worthy of study in its own right. Likewise the extension to more than one space dimensions is important for those interested in solving real problems, and this book is not going to help in this context.

There are a number of excellent books dealing with theoretical and practical aspects of using spectral methods. In comparison the current text is pitched as a scholarly, academic treatment of the subject matter, motivated by 'the research on finite-difference schemes'. Whilst a number of subjects are covered in detail, and many new topics such as filtering, Gibbs phenomenon, which are barely touched upon in other texts, are discussed at length here, nevertheless, the serious practitioner of spectral methods will need to consult other texts to fill in missing gaps. For instance, an extended and more comprehensive description of stability, may be found in the book by Canuto et al.

Overall, this book will be a useful and welcome addition to the list of texts dealing with spectral methods. Graduate students and those new to spectral methods will find this to be an excellent introductory text conveying the key elements in a concise and lucid style. There is an extensive bibliography for those wishing to pursue a topic in greater depth.

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**The Augmented Spherical Wave Method. A Comprehensive Treatment**, by V. Eyert, Berlin, Springer, 2007, x + 320 pp., £54.00 (hardback), ISBN 9783540710066. Scope: monograph. Level: specialist.

Since the introduction of density functional theory in the 1960s, numerous methods have been developed which have enabled full quantum mechanical electronic structure calculations to be performed on more and more complicated materials. The periodic nature of crystalline solids allows the fundamental problem to be reduced to one of solving Schrödinger's equation on a single cell of the atomic lattice, typically containing only a few atoms. This is still a formidable challenge and one of the most common approaches is to use a variational principle, which in turn requires the single-particle wave function to be expanded as a linear combination of a suitable set of basis functions. The coefficients in this expansion must then be determined numerically by seeking to minimise a certain functional, which is essentially the total energy of the system.

The choice of the basis functions is crucial to the success of this general approach and many variants, usually involving a number of simplifying assumptions, have been investigated, including the augmented plane wave method, the linear augmented plane wave method, the linear muffin-tin orbitals method, as well as the augmented spherical wave (ASW) method. Eyert's book is a detailed and comprehensive description of the last of these, including some generalisations of the original method as proposed by Williams et al. in 1979 [*Phys. Rev. B* 19, pp. 6094–6118]. The complexity of the associated theory is indicated by the 130 pages of appendices which make up nearly half the volume. This is a highly specialised book which is likely only to be of interest to those already familiar with the theoretical techniques of modern condensed matter physics. On the other hand, for those wishing to embark on computations using the ASW method it will no doubt be an invaluable resource.

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