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SENIOR LEVEL

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Book Reviews / *Critiques de livres*

A Student Manual for "A First Course in General Relativity", by Robert B. Scott, Cambridge University Press, 2016, pp. 310, ISBN 9781139795449, price 29.95.

This is an excellent companion volume for anyone contemplating teaching a first course in General Relativity. Ideally the course manual should be the corresponding book by Bernard Schutz called "A first course in general relativity" also published by Cambridge University Press. The book by Schutz is an excellent first course in General Relativity, which presents the subject by first explaining in detail special relativity in the first 4 chapters followed by 8 chapters which gently lead the student into the complexity of General Relativity where it starts with the definition of curved manifolds followed by physics in curved spacetime, to Einstein's equations and then followed by applications to gravitational radiation, spherical solutions for stars, black holes and ending with a short introduction to cosmology.

Scott's Student Manual follows Schutz' book exactly, chapter by chapter, indeed the chapter headings in the two books are identical. There are according to Scott, 388 exercises in Schutz's book. Scott suggests that the interested learner do each and every one of them. In Scott's book, he does give the solution of most of the exercises of Schutz and he gives many more solved supplementary exercises, in addition to some exercises for which the solutions are not provided. Scott uses the notation eq.(n.m) to denote the exercises/equations in Schutz's book while the notation eq.(n.m) to denote exercises/equations in the Student Manual. The solutions are always placed in a grey background so that it is clear when one is reading a solution as opposed to the exercises themselves. Scott goes through very much detail in explaining the solution, hence some might find the solutions a bit laborious, however, they are very pedagogic. Scott does this expressly, his aim being "to be complete, to spell it all out". Scott also has provided an accompanying Maple worksheet, which is available for download from the Cambridge University Press web-site.

The first 4 chapters of Scott's book are on special relativity. The subject is presented to the reader through many exercises that are based on very fundamental aspects, starting with exercises on the basic definition of natural units, then the principles of special relativity: that no observer can measure the absolute velocity of any other observer and that the speed of light is universal, invariant for all inertial observers. These are followed by two chapters of exercises on the notions of vectors and tensors in Minkowski spacetime and ending with a chapter on the definition of a perfect fluid in special relativity.

Then come the exercises on the heart of the matter, General Relativity. The next four chapters, 5 through 8, give exercises on the mathematical structure and the notions of

differential geometry leading to the Einstein equations. I have done several of the problems in each of the chapters and I find some of them quite challenging. I compared my solutions to those offered by Scott and I am happy and relieved to know that they compare pretty well with those provided, the difference being largely that Scott gives far more details! There are in depth exercises on the first corrections to the Newtonian theory and how they arise in Einstein's theory, which is very educative.

The final four chapters, 9 through 12, are exercises on the fundamental applications of Einstein's theory, to gravitational radiation, solutions (spherical) for stars, black holes and cosmology. These chapters capture the essence of the excitement of General Relativity. They correspond to predictions of Einstein's theory that go beyond the Newtonian theory, including time dependent phenomena, strong gravity and gravitational collapse, event horizons and a first exposure to cosmology. The exercises are again very detailed and expose the various pedagogical aspects of the rather theoretical analyses in Schutz's book.

Thus in summation, this book is a perfect companion to a textbook for teaching a first course in General Relativity. Ideally, it goes hand in glove with the book by Schutz. However, it could be used as a source book of exercises to accompany any similar course based on another book (like that of Hartle or Carrol). The instructor could use the book to assign solved problems and unsolved problems suitable for homework problems.

Manu Paranjape,
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A Well-Ordered Thing, by Michael Gordin, Princeton University Press, 2019, ISBN:978-0-691-17238-5, pp. 351, price 22.58.

Michael Gordin's "A Well-Ordered Thing" is a carefully researched and scholarly account of the life and surroundings of Dmitrii Mendeleev, the late 19th century co-inventor of the periodic table. Gordin covers Mendeleev's academic beginnings, his famous work on the periodic table, and takes time to discuss the lesser known pursuits of Medeleev: his economic and political thought, his work in industry and in service to the Russian empire, and his investigation into the Spiritualism movement. Mendeleev's diverse interests are used to explore the setting Mendeleev lived in; indeed, Gordin emphasizes that the book is not so much the story of Mendeleev as it is an examination of imperial St. Petersburg.

Due to its emphasis on St. Petersburg, the book is a biography of a scientist without being a scientific biography. With the exception of the famous periodic law, to which Gordin devotes a chapter, Medeleevs scientific thought is presented in an incidental way. Further, the scientific context in which Medeleev worked is never discussed in detail. Consequently Gordin's priorities may not align with those of a scientist-reader. Nonetheless, the book contains some interesting scientific details. Gordin stresses that Medeleev's thinking on the periodicity of properties of the elements stemmed from a pedagogical need: to organize the known elements into a form suitable for a first year chemistry textbook. I also found Medeleev's views on the ether to be of interest. Medeleev believed the ether was composed of particles which could be placed in the periodic table and attempted to predict properties of the ether by using his periodic law, just as he had predicted the existence and properties of unknown elements.

Gordin explores in depth Mendeleev's economic and political thought, and his role in shaping imperial policy. Gordin stresses how, to Mendeleev, scientific societies were models for how technical expertise could be employed by the empire. The book emphasizes Medeleev's "Imperial Turn", a transition from a focus on local affairs in St. Petersburg to a top-down approach to enacting reform. In Gordin's analysis, this turn was initiated by Mendeleev's rejection from the St. Petersburg Academy of Sciences, as Mendeleev had taken the Academy to be a model of how reform could be organized locally. Gordin also argues that the ensuing outrage in the popular press made Mendeleev's reputation.

"A Well-Ordered Thing" aims to explore imperial St. Petersburg through one of its great citizens. In his writing, Gordin has emphasized analysis over narrative. In some places the analysis felt stretched or obvious. For instance, Gordin draws a parallel between Mendeleev's work on gases and his meteorological work, noting that in both cases he was "amassing data on irregularities in order to determine laws", but the parallel could have been made to nearly any scientific work. As well, the lack of narrative left me without a clear sense of Mendeleev as a person. In general though the historical analysis makes interesting points, especially regarding Mendeleev's rejection from the Academy and consequent Imperial Turn, and the book largely succeeds in its aim.

Alex May, PhD student,
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Fearful Symmetry: The Search for Beauty in Modern Physics, by A. Zee, Princeton University Press, 2016, ISBN 9780691173269, pp. 376, price 31.99.

There are few popular physics books which are worth recommending to a student beginning a new subject. Tony Zee's "Fearful symmetry" is one of them. This book should be productive reading for students studying particle physics or group theory in physics. This is not only because the book presents technical material honestly, but also because the book reads easily. To achieve this, Zee maintains the unusual writing style he is known for in his textbooks — short and pointed sections colored with references to art, literature and anecdote.

Zee covers some of the usual ground for a popular physics book, for instance quantum mechanics, relativity, and the Standard Model. Additionally however he reaches topics rarely touched: groups, non-abelian gauge theory, spontaneous symmetry breaking and supersymmetry. By presenting these topics and tying them to a unifying theme of symmetry and the aesthetic sense of the theorist, Zee presents one of the most recognizable portraits of work as a theoretical physicist available in popular work.

To Zee, beauty, largely as expressed through symmetry, is a powerful guiding force in theoretical physics. Also running throughout the work is a persistent reference to God or a Designer. Usually among theorists such references are linguistic conveniences or metaphors (as was the case for Einstein, a frequent source of such usages), though this subtlety is an inevitable point of confusion. In Zee's case however the references are more than metaphor, as he believes in a presence of some kind responsible for creating the universe. Indeed, Zee views the aesthetics of the universes design, as evidenced through the role of symmetry, along with the basic fact of the universes comprehensibility as evidence for this deistic view.

Zee's views on deism and aesthetics contribute much of the uniqueness of the book. At times though Zee risks portraying theoretical physics as a mystic art, and it is worth emphasizing a counterbalancing view. My own view is that theoretical physics is not at all divorced from observation - and so not at all a mystic art - even in a case such as string theory. In that case, theorists have chosen to focus on the core principles of quantum mechanics and gravity, and work mathematically to tie them together into a consistent theory. Those principles however are well grounded in experiment. Momentarily ignoring some details and beginning from basics is sometimes necessary to make conceptual jumps. In fact, Zee makes a similar point in the context of general relativity - Einstein did not arrive at his theory by studying observations of the orbit of Mercury, but by revisiting long known simple observations.

While Zee's views may not align precisely with my own, he has written an excellent book. It will be of interest not only to the new student, but also to any artist or layperson interested in beauty. Zee has made great progress in making the beauty

of symmetry in physical law accessible for a wide audience.

Further Adventures of the Celestial Sleuth, by Olson, Donald W., Springer, 2018, pp. 334, ISBN 978-3-319-70319-0, price 32.84.

I selected this book because I was intrigued by its premise: using astronomy to solve mysteries regarding the time, date and location of the origins of works of art. As a secondary school physics teacher, I am always interested in finding other ways to teach students about the applications of the knowledge and skills we teach them in school, and this text did not disappoint.

The book reads much like a Sherlock Holmes case file. Donald W. Olson describes how he and his team from Texas State examined paintings, battles, photographs, and literature through an astronomical lens, to locate, re(examine) and challenge their understandings of the works, as well as the conclusions of other researchers. Clues, such as historical documents (e.g., letters, train schedules, tide tables, newspaper clippings) are combined with modern means (e.g., computer planetarium simulations), to build their own portrait, which includes information about the astronomy, as well as the artists themselves.

Broken into four parts — *Astronomy in Art, Astronomy in History, Astronomy in Literature, The Terrestrial Sleuth* — Olson begins each chapter outlining the questions he and his team had set out to solve. In Part One, the challenge was often to deduce the location and date for a painting. Olson works with an underlying assumption that the artist included an accurate representation of what was present in the night sky from their location. From this, he uses stories about the artists and other references to the work, to deduce his answers. Olson also includes in this section an examination of *Times Square Kiss* — and specifically the shadows on the buildings — to add more information to the ongoing discussion on the as-yet unidentified woman and sailor. In Part Two, the team sought to better understand the factors which influenced strategic battle preparations (such as the case for the Battle of Stirling Bridge or the Battle of Normandy), and worked with data to highlight misconceptions. Part Three focuses on literary passages, to determine their accuracy, in terms of celestial movements and season. Olson, uses knowledge of each author's astronomical competence to frame the possible legitimacy of the passages, and then move on to determine whether authors had accurately described astronomical events or celestial movements based on the season or location of a scene. In the final part, Olson turns to two final puzzles: a railway and locating the Millais oak tree.

This is the second ***Celestial Sleuth*** book, and Olson makes reference to other case files in that volume — although not required to understand what is discussed here. The background knowledge required to understand the text is at the secondary level, and new material and terminology is explained succinctly to allow the reader to follow key ideas of analyses. For me, I felt it did provide some interesting options from which to teach physics at the secondary level, such as Chaucer's description of the moon's path in terms of Kepler's Laws of motion. For the higher education educator, I feel the book gives enough information to provide a roadmap of the kinds of information and tools one would need to endeavor on a similar quest.

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On Gravity—A Brief Tour of a Weighty Subject, by Anthony Zee, Princeton University Press, 2018, ISBN 9780691174389, price 19.95, www.press.princeton.edu/titles/11235.html.

In the preface, Anthony Zee tells his readers that **On Gravity** is supposed to bridge the gap between popular books and textbooks on Einstein gravity. After reading the 142 pages of the main text and the eight page appendix, I am convinced that he succeeded. The area between popular books and textbooks is somewhat of a no man's land, and especially for individuals with an interest in a particular field (say, gravity, for instance) this can be quite frustrating. What should you read when you already understand the basic idea of gravitation, know the main players in the history of its development, and have perhaps watched a few documentariers on the topic as well?

Well, you should read **On Gravity**.

The book is divided in four parts which consist of a handful of chapters each, and each chapter is again split into digestible sections with fitting and sometimes tongue-in-cheek headlines. Zee is one of the few physics authors who write so fluently and seemingly effortlessly that I didn't even realize I was already halfway through the book. His tone, as usual, is relaxed, conversational, and laid-back, making the seeminlgy complicated topic of Einstein's General Theory of Relativity a lot more approachable.

In part I, Zee introduces gravity as the weakest of the four fundamental forces in our Universe, and explains the nature of electromagnetic (and gravitational) waves. In part II we learn about Einstein's main idea: the principle of relativity. We also learn why we shouldn't call it "principle of relativity." Part III is devoted to a detailed explanation of the action principle in both classical mechanics and gravity theory. Finally, in part IV we learn about black holes, Hawking radiation, gravitons, as well as the concepts of dark matter and dark energy. In the grand finale Zee highlights the importance of gravitational waves, which, and that's the hope, will provide scientists with new powerful methods of observing and understanding the Universe.

On Gravity takes its time with the reader, and most concepts are explained brilliantly and in quite some detail: the idea of relativity, the action principle, gravitational waves, and even curved spacetime (in the appendix). I wish more professors would read this book and use these explanations in their undergraduate courses! The explanation of Hawking radiation, on the other hand, after a thorough introduction into the quantum uncertainty principle, seems a bit rushed and barely surpasses that given in popular science texts. Moreover, what I would have liked to see (and what is lacking in Zee's treatment) is a deeper discussion of the *limitations* of General Relativity. The Evergreen, a.k.a. the quest for the still elusive theory of quantum gravity, is clearly adressed, but problems at the classical level (say, in the form of gravitational singularities inside of black holes) are not mentioned. I think this is a missed opportunity to make this book more balanced.

Overall, **On Gravity** is a fantastic read. It is supplemented by a whopping 12 page index as well as 13 pages of annotations providing additional anecdotes, insights, and kindhearted encouragements to the reader. Zee's book might be a good choice for undergraduate students who are contemplating to enter the field but don't want to read 800 pages in a standard textbook. And if you work on gravity yourself, and you want to talk to your friends a bit more about your work, give them this book. Seriously. Zee's unique style will surely entice them and present research in gravity from its truly attractive side (pun intended).

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Practical Bayesian Influence: A Primer for Physical Scientists, by Coryn A. L. Bailer-Jones, Cambridge University Press, 2017, pp. 295, ISBN: 9781316642214, price 105.95.

Few fields are as fraught with a history of controversy as that of Bayesian inference. Although born in the 18th century in the work of Bayes and Laplace, its "subjective" view of probability fell out of favour in the 20th century after Neyman, Pearson, and others developed statistics based on a frequentist interpretation of probability. In the

former, probability measures degrees of rational belief in the truth of a proposition; in the latter, probability is viewed as the limiting frequency in an infinite number of trials.

More recently, there has been a tremendous resurgence of Bayesian methods, which are at the heart of many successful methods in data science and machine learning. With this growth in popularity has come the need to teach the methods to broader scientific audiences. However, perhaps because of its "insurgent" past, many texts have been original and quirky. Think of the books by Harold Jeffreys, Edward Jaynes, D. S. Sivia, and David MacKay for example. Perhaps what makes such books brilliant and inspirational also makes them harder to teach from. Insights that appear deep to the expert may just confuse the student. (The same critique has been made of the Feynman Lectures.)

Coryn A. L. Bailer-Jones' book is an interesting pragmatic alternative. It is straightforward and clear, if not always original — many of its examples and ways of presenting material come from the "quirky" books above. Still, it may be easier to follow than other, deeper treatments. For example, Chapter 9 goes carefully through the procedure for curve fits using Markov-Chain Monte Carlo (MCMC) and also offers a treatment of data outliers using mixture models. The latter example provides a simple way to automatically identify and, in effect, exclude "bad" points from otherwise "good" data. And the introductory discussion to model selection — clarifies many points, such as why use odds ratios, that are often glossed over in other discussions.

An attractive feature of the book is its many numerical illustrations, supported by explicit code available online. Perhaps unfortunately, the chosen language is R, an open-source program from the statistics community that is not widely used by the physics community (at least that part I am familiar with). Matlab, Mathematica, and Python are more common. Of course, these languages share common features, and transcribing a routine into your favourite language can be a good exercise. A similar critique is that the notation, for example E[x] for expectation rather than <x>, reflects conventions of statistics more than physics.

In short, Bailer-Jones has written an attractively brief, direct, "practical" introduction to Bayesian Inference. While its presentation and examples are often standard, it is well organized and very clear and should be much appreciated by upper-level undergraduates looking for an introduction to the field, assuming they do not get too hung up on the use of R and statistics notation. For graduate students seeking more depth and derivations, *Bayesian Probability Theory*, by Wolfgang von der Linden, Volker Dose, and Udo von Toussaint, is a comprehensive alternative. And, for inspiration, I still prefer Sivia's *Data Analysis: A Bayesian Tutorial*.

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