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Modern Electrodynamics FREE

Modern Electrodynamics.. Andrew Zangwill 998 pp. Cambridge U. P., New York, 2013. Price: $85 (hardcover) ISBN 978-0-521-89697-9.

James S. Russ

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BOOK REVIEWS

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Modern Electrodynamics. Andrew Zangwill. 998 pp. Cambridge U. P., New York, 2013. Price: $85 (hardcover) ISBN 978-0-521-89697-9. (James S. Russ, Reviewer)

Modern Electrodynamics is a recent entry into the list of texts available for a first-year graduate course in electricity and magnetism, a rite of passage for every beginning physics graduate student. The consequences of Maxwell's equations connect experiment and theory across a wide range of disciplines and scales in contemporary physics research, from devising field configurations to contain plasmas or hold single electrons to using electromagnetic probes to deduce the structures of the early universe. The subject matter is not always easy to grasp. It requires both mathematical facility and physical insight. Zangwill provides a quotation from Max Planck to begin Chap. 15 on general electromagnetic fields: "When we turn our attention to the general case of electrodynamics…our first impression is surprise at the enormous complexity of the problems to be solved." However, in my course using Zangwill's text I conclude the syllabus with the observation that "The material is formidable, but truly worth mastering."

Zangwill, a condensed matter theorist, has taken a different point of view in developing his text than most of his recent predecessors. Condensed matter physics and biological physics present some challenging applications of electromagnetic theory in understanding the energetics of charge transport or magnetic dipole orientation in cells or novel materials. Zangwill covers the important conventional topics of classical electrodynamics, but enlivens his discussion with well-chosen examples from a range of current topics to justify the adjective "Modern" in the title.

The challenge of understanding classical electrodynamics has attracted extraordinarily talented investigators over the past four centuries. Zangwill supplies quotes and examples from early biological physics investigators (Galvani studying electrical stimulation of frogs) through the amazing experimental achievements of Priestly, Ampère, and Faraday in delineating the fundamental properties of electrical and magnetic forces and into our time. Each chapter has a section entitled Sources, References, and Additional Reading that contains intriguing articles and books. Many of the entries in those sections were new to me, and I found them well worth exploring. Zangwill writes as a story-teller as well as physics lecturer. In discussing the concept of the Faraday cage, he quotes from Faraday's diary about building a cube 12 ft on a side, covered with tinfoil and copper wire. Faraday went inside and had the conducting surface charged by a static electric generator, while he looked for evidence of a field. This was no microscopic investigation of the Faraday cage concept. The book also boasts some superb graphics, like the figure showing Maxwell's depiction of the field lines and equipotentials at the edge of a long parallel plate capacitor.

The preface gives insight into the somewhat idiosyncratic structure of the text. Zangwill experimented with different organizational styles. The current version presents material—998 pages worth—in a style that he finds most logical. Overall, the organization is traditional, beginning with mathematical preliminaries. Statics and dynamics are treated separately, then unified via special relativity. Each chapter has a generous set of problems, chosen from a wide variety of sources. Some problems are quite specific, aiming to elucidate one particular point in the text. Others invite the student to expand his/her understanding of the link between electrical and magnetic fields such as a problem showing that there is an electrostatic equivalent of the magnetic Helmholtz coil configuration. A few problems present significant challenges in identifying the physics needed to make a solution.

Some of the material presented is quite innovative and non-traditional. Because physics graduate programs in many institutions have students heading into diverse specialties via interdisciplinary research, these expansions of topics are a real strength of this text. Examples of this sort are discussions of the energy barrier for a potassium ion in aqueous solution to move through a channel in a low-dielectric protein tubule and of the relation between Fick's law for the diffusion current of charge carriers and the resting potential across a cell wall due to potassium ion diffusion.

Using the text has presented me with some unexpected challenges. Zangwill notes that each instructor will want to decide on topics and order of presentation—always true, of course. What is different here is that topics pop up in pieces in unexpected places, to be referenced several chapters later in a different discussion. One such case is the treatment of the expansion of $1/|\mathbf{r} - \mathbf{r}'|$ in spherical polar coordinates. I would expect to find this as part of a systematic treatment of formal solutions to the Laplace equation in potential theory. Zangwill not only introduces it three chapters before his potential theory section but also relegates formal treatment of spherical harmonics, Legendre functions, and Bessel functions to an Appendix. This discontinuity in treatment can be solved, of course, by appropriate course notes. However, the scattered nature of the material here, in contrast to more coherent presentations in other texts, bothered some of my students. Another surprise is the treatment of stored energy in electrostatic or magnetostatic fields for: (a) a source-free configuration and (b) an attached charge or current source. Zangwill introduces a Legendre transformation to modify the source-free energy in going from (a) to (b), rather than making a physics argument based on the difference in what constitutes an isolated system in the two configurations. Using a Legendre transformation to introduce the additional energy term may be natural from a condensed matter point of view, but it does not seem to me to contribute to the clarity of this important discussion. Zangwill's use of the Minkowski metric in the discussion of special relativity is also unusual.

For a book entitled *Modern Electrodynamics*, I am disappointed at the mere passing mention of computational electrodynamics, rather than a serious treatment of the power of computational approaches to static and dynamic real-world problems. The accuracy of the electromechanical and magnetostatic force calculations by such methods makes possible the design of large superconducting magnets for MRI scanners and particle accelerators and detectors, for example.

The classic electrodynamics text for the past four decades has been the monumental work by J. D. Jackson, the book from which most current-generation physicists took their first course. In Jackson's work, the examples are sophisticated and fine points of the physics are often relegated to problems. The Zangwill approach is different. For example, he compares the average of quantum calculations with classical models for material properties like dielectric constants, magnetic permeability, and skin depth in conductors; areas in which the classical approximation of an abrupt change at a surface is unphysical but nevertheless gives a good description of observations for distances large compared with atomic sizes. The quantum computations demonstrate that the distance scale for field variations from equilibrium values inside and outside material is indeed characterized by an atomic distance scale, justifying the classical approach. While I find that Zangwill's presentation is frequently not as thorough as that of Jackson on a given topic, Zangwill's approach is easier for a beginning student to navigate. I am happy to have both resources on my bookshelf.

James S. Russ is professor of physics at Carnegie Mellon University. His research area is experimental high energy physics. In his career, he has been involved in building and testing many pieces of experimental equipment that rely heavily on the topics discussed in this book.

Infrared Astronomy—Seeing the Heat: From William Herschel to the Herschel Space Observatory. David L. Clements. 289 pp. CRC Press, Boca Raton, Fl. 2015. Price : $44.96 (hardcover). ISBN 978-1-4822-3727-6. (George H. Rieke, Reviewer.)

I have surveyed a dozen current offerings for introductory general education astronomy courses, average price $150. They generally are elaborately produced with many pages of beautiful color pictures and contain far more material than typical students for this course could ever assimilate. They cover the subject from absolute magnitude to zodiac. Most are sufficiently didactic that they will never be kept as treasured mementoes after completing a course. In fact, most will be sold back to bookstores as soon as possible to recoup some of the capital investment.

We need alternatives. David Clements' *Infrared Astronomy—Seeing the Heat* shows one possibility. It is shorter, less expensively produced, and cheaper ($45 or less). It covers much of current astronomy but with a lighter touch. And it does not try to cover too much. The focus on infrared astronomy provides a coherent entrance to a majority of the "hottest" current topics in astronomy generally but allows doing so with a smaller burden of prior material. The book is clearly written with simple and useful diagrams. Each chapter starts with an anecdote, usually about the author, which lends a personal dimension to the discussion and should help general education students identify with the topics. This also lends the book a certain charm for those who might just read it on their own.

As an example, consider the chapter on infrared galaxies, a topic where Clements has made a number of contributions. The chapter starts with a self-deprecating story about observing on Mauna Kea, then an amusing follow-up anecdote. It next gives a short, clear overview of galaxies for general background, segueing quickly to the aspects of particular interest in the infrared: the interstellar medium, emission by dust particularly in the far infrared, and central black holes and active nuclei. These points are illustrated with a more detailed discussion of the Andromeda Galaxy (M31) as a normal galaxy and the extension of that discussion to many galaxies with results from the Infrared Astronomical Satellite (IRAS). Next, the chapter covers active galactic nuclei (AGNs), nicely explaining the chaotic variety that was brought into order with unified theories. This brings up the question of the relation of an AGN to its host galaxy, leading to a discussion of starbursts and the importance of galaxy interactions in initiating all kinds of transformations and activity, including vast changes in morphology as well as triggering violent episodes of star formation and probably feeding central black holes to cause them to flare into AGNs. The chapter ends with a succinct summary.

At the same time, the book misses some points relevant to the goals of general education instruction. The author's perspective begins roughly when he entered the field, 25 years ago. I feel the same way, but I entered the field 20 years before he did. Maybe these views can be reconciled because the growth of infrared astronomy has been so rapid that looking back would always make the past seem modest compared with the present and future. With the launch of the James Webb Space Telescope (JWST), the basic capability at many infrared wavelengths will have doubled roughly every ten months continuously for 50 years (capability as in the Bahcall decadal survey of 1990, proportional to the number of pixels in the largest available detector array, divided by the square of its detection limit in flux units; basically its speed in survey observations). What fueled this incredible advance? It was a combination of the technical skills of those originally attracted into the area (nearly all physicists, not astronomers); the spinoffs of the military infrared detector development, particularly large format detector arrays; and the foresight of science administrators, particularly in NASA, to gamble on funding this new and untried technique. This growth provides an ideal opportunity to cast science as an adventure and to show the forces that drive progress.

There are other possibilities for innovative general education courses that might also be considered. They include the excellent books by Marcia Bartusiak, Chris Impey, and Brian Greene, focused on individual topics that could be covered in depth. Unfortunately, books of this general type sometimes have a limited life before they become out of print and hard to obtain in the numbers required for use as a text.

As anyone who has written a book knows, errors are the authors' nightmare and can never be banished. However, this book contains a number of significant ones that will need correction if it is used for a course and that should be noted by other readers: Page 16: As correctly discussed later (e.g., page 197), most of the helium was created by thermonuclear fusion early in the Big Bang, not in stars. Therefore, the statement that "At this early stage of the Universe nearly all matter was in the form of atomic hydrogen" is not correct. Page 37: The description of the operation of a CCD (charge coupled device) is misleading. The process is not critically dependent on the p and n doping nor are the photons detected by knocking charges out of capacitors. Instead, charge is freed when photons are absorbed in the material and this photo-generated charge is collected by voltages established at electrodes that define the pixels; the collected charge is read out by passing it from one electrode to another by manipulating voltages, so this charge can be brought to an output amplifier at one edge of the detector array. Page 41: The detectors for the Infrared Array Camera (IRAC) for the Spitzer telescope are not read out by CCDs. They have a dedicated amplifier for each detector element in the array and the outputs of these amplifiers are brought to the array output by electronic switching using metal oxide semiconductor field effect transistors (MOSFETs). This architecture is standard for virtually all infrared arrays. Page 46: The footnote implying that the H photometric band was only usable after observations were obtained from mountain tops is incorrect. It is as clear an atmospheric window as J and K. Page 63: One of the most important early discoveries from infrared observations of planets was the internal energy of the gas giants, found with the University of Arizona Lunar and Planetary Laboratory 61-Inch Telescope in 1965 by Frank Low and confirmed by his group with the Lear Jet shortly thereafter. It is not clear why this is omitted. Page 67: The major role of the space-based Wide-Field Infrared Survey Explorer (WISE) in finding asteroids is omitted; the Near-Earth Object WISE (NEOWISE) is particularly important for hunting objects in the inner Solar System. Page 140: Much more was known about extragalactic objects in the mid- and far-infrared prior to IRAS than is indicated here. Significant work in the far-infrared had been done with the Lear Jet telescope and with balloon-borne telescopes and exploratory measurements had been made at 350 μm from the ground. The 100 μm peak in star forming galaxy spectral energy distributions was well known—it was by no means discovered with IRAS. IRAS provided measurements of far more galaxies to much fainter limits than previously, but its "discovery" of this phenomenon is vastly overstated. Page 147: The mid-IR emission from AGN was well documented long before the launch of IRAS. In fact, because its very large beam captured significant emission from the AGN host galaxy along with that from the nucleus, and it had no detectors operating at wavelengths shorter than 12 μm, IRAS was unable to study the hot dust in AGNs well, contrary to the statement that IRAS discovered this dust. Page 152: The story about the far infrared emission of M82 being first discovered by IRAS, leading to the identification of the galaxy responsible, is just that—a story. In fact, a detailed paper on observations and modeling of the star formation in the galaxy, including the energy released in the far infrared, was published three years before the launch of IRAS. This paper also introduced the starburst terminology.

George Rieke is a Regents Professor of Astronomy and Planetary Sciences, The University of Arizona. He has published 3 books and about 500 peer-reviewed articles, nearly all on infrared astronomy. He was Principal Investigator of the MIPS instrument on Spitzer and is science team lead for the MIRI instrument on JWST. He is a member of the American Academy of Arts and Sciences and the National Academy of Sciences.

BOOKS RECEIVED

Building the H Bomb: A Personal History. Kenneth W. Ford. 234 pp. World Scientific, Singapore, 2015. Price $24 (paper) ISBN 978–98146318793.

To Explain the World: The Discovery of Modern Science. Steven Weinberg. 440 pp. Harper Collins, New York, 2015. Price $28.99 (hardcover) ISBN 978-0-06-234665-0.

Simulations of Oscillatory Systems with Award-Winning Software, Physics of Oscillations. Eugene I. Butikov. 364 pp. CRC Press, Boca Raton, FL, 2015. Price $80.96 (hardcover) ISBN 978-1-4987-0768-8.

Physics on Your Feet: Berkeley Graduate Exam Questions or Ninety Minutes of Shame but a Ph.D. for the Rest of Your Life. Dmitry Budker, Alexander O. Sushkov, and Vasiliki Demas. 216 pp. Oxford U.P., New York, 2015. Price $39.99 (paper) ISBN 978-0-19-968166-2.

Physics Curiosities, Oddities, and Novelties. John Kimball. 379 pp. CRC Press, Boca Raton, FL, 2015. Price $31.46 (paper) ISBN 978-1-4665-7635-3.

Fundamentals of Thermoelectricity. Kamran Behnia. 248 pp. Oxford U.P., New York, 2015. Price $98.50 (hardcover) ISBN 978-0-19-969766-3.

Neutron Interferometry: Lessons in Experimental Quantum Mechanics, Wave-Particle Duality, and Entanglement, 2nd ed. Helmut Rauch and Samuel A. Werner. 459 pp. Oxford U.P., New York, 2015. Price $110 (hardcover) ISBN 978-0-19-871251-0.

Principles and Applications of Fourier Optics. Robert K. Tyson. 116 pp. IOP Publishing, Bristol, UK, 2014. Price $190 (hardcover) ISBN 978-0-750-31057-4.

Ultrafast Spectroscopy: Quantum Information and Wave Packets. Joel Yuen-Zhou, Jacob J. Krich, Ivan Kassal, Allan S. Johnson, and Alán Aspuru-Guzik. 145 pp. IOP Publishing, Bristol, UK, 2014. Price $190 (hardcover) ISBN 978-0-750-31063-5.

Symmetry and Collective Fluctuations in Evolutionary Games. Eric Smith and Supriya Krishnamurthy. 240 pp. IOP Publishing, Bristol, UK, 2015. Price $190 (hardcover) ISBN 978-0-7503-1138-0.

Scientific Basis of the Royal College of Radiologists Fellowship: Illustrated Questions and Answers. Malcolm Sperrin and John Winder. 258 pp. IOP Publishing, Bristol, UK, 2014. Price $190 (hardcover) ISBN 978-0-7503-1059-8.

Energy Revolution: The Physics and the Promise of Efficient Technology. Mara Prentiss. 349 pp. Harvard U.P., Cambridge, MA, 2015. Price $29.95 (hardcover) ISBN 978-0-674-72502-7.

The Art of Electronics, 3rd ed. Paul Horowitz and Winfield Hill. 1223 pp. Cambridge U.P., New York, 2015. Price $120 (hardcover) ISBN 978-0-521-80926-9.

Physical Hydrodynamics, 2nd ed. Etienne Guyon, Jean-Pierre Hulin, Luc Petit, and Catalin D. Mitescu. 536 pp. Oxford U.P., New York, 2015. Price $74.95 (paper) ISBN 978-0-19-870245-0.