BOOK REVIEWS

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Probing the Sky with Radio Waves: From Wireless Technology to the Development of Atmospheric Science. Chen-Pang Yeang. 376 pp. University of Chicago Press, Chicago, IL, 2013. Price: $60.00 (hardcover). ISBN 13-978-0-226-01519-4. (Russell Philbrick, Reviewer.)

This book focuses on the early steps in one of the remarkable advances of 20th century science, the discovery of the ionosphere, which led to mankind's step into the Space Age. Yeang recounts the research and the struggles that led to this discovery during the first half of that century, and stimulated the curiosity that resulted in space exploration during the second half. The people and the events of those early days are chronicled in a fascinating way by the author. It is interesting to learn about the many steps, both experimental and theoretical, taken by researchers, thinkers, and tinkerers. Although some of the many theories and early experiments with radio waves were correct, many were not. But all contributed to a discovery that whetted appetites to learn more about "what is up there?"—leading rapidly to discoveries about the upper atmosphere and the space environment.

Wireless telegraphy originated in the 1890s, following soon after the dipole experiments of Hertz in Germany (1886–1889). In 1891, British scientist George Minchin conducted a transmission experiment over a distance greater than 100 ft, and that distance was quickly extended at laboratories in Europe. In Italy, Marconi transmitted a signal that reached 3 km in 1894. A neighbor of Marconi's family in Bologna, Augusto Righi, who invented the induction electrometer and later wrote an early paper on wireless telegraphy, helped to inspire the work of Marconi. But Marconi found little interest and support for his experiments in Italy. A family friend at the U.S. Consulate in Bologna arranged a trip to England for him in 1896, at age 21. There he obtained support for his experiments on wireless telegraphy from the British Post Office. During the next few years, he conducted experiments that by 1899 extended the range over which wireless signals could be sent to almost 50 km. These longer distances caused scientists to become interested in the bending of waves around the Earth. In collaboration with British scientist John Fleming at University College London, Marconi prepared a high-power transmitter near Cornwall and embarked on an experiment to receive signals across the Atlantic. He first erected a receiving antenna at a station on Cape Cod, but a storm destroyed it so he relocated his station to Newfoundland. His laboratory assistants in England were instructed to send a series of three dots (SSS in Morse code) several times around noon. At the station in Newfoundland, Marconi and his assistant, George Kemp, heard a series of sharp clicks four times. The first signals were received on 12 December 1901, and the event was reported to the world two days later by the *New York Times*. These results attracted further international attention and confirmation, from signals Marconi received on the SS Philadelphia sailing from England to New York in February 1902. His efforts were recognized with the 1909 Nobel Prize.

We must admire the work of the scientists as they approached this new area of exploration, with its experimental and theoretical questions to test, eventually resulting in a new chapter in the book of knowledge. Ideas and experimental results were often communicated by letters between colleagues, or spread from teachers to students. Important contributions to theory were made by mathematical physicists from Cambridge University. Solutions to propagation problems required Bessel and Hankel functions and Legendre polynomials to formulate theories in spherical coordinates. British, French, and German theorists led most of the early physical modelling. Soon after Marconi's 1901 experiment, the American Arthur Kennelly and the English scientist Oliver Heaviside independently postulated a high-altitude reflecting layer that became known as the Kennelly–Heaviside Layer. (Many people today, if they were able to make a connection, would associate the Heaviside Layer with Andrew Lloyd Webber's musical "Cats," based on a T. S. Eliot poem. When Old Deuteronomy takes Grizabella on a journey to the ethereal or heavenly place for her reincarnation, they travel to the Heaviside Layer; there is no indication that this was the ionosphere.) The first theory for bending of electromagnetic waves around the Earth was put forth by MacDonald at Cambridge University, near the turn of the century. This surface wave model followed in a manner similar to diffracting acoustic waves and it was the focus of the theorists in England, France, and Germany during the next decade. Experimental results came primarily from collaborations between U.S. and English scientists, who extended Marconi's experiments. As experiments continued to provide more data, wave diffraction ideas gave way to electron scattering models. We can only imagine the efforts of scientists performing those experiments a century ago, when they had to make their own capacitors and wind their own inductors; experimental research proceeded a bit differently in the days before our ability to shop at a local Radio Shack or receive parts overnight from Newark or Allied Electronics. But it was not until the contributions of many scientists that it was possible for Edward Appleton to confirm the existence of and describe the ionosphere in 1927, for which he was awarded the 1947 Nobel Prize.

Yeang presents a scholarly and fascinating account of how early research with radio waves opened many pathways to advance electromagnetic wave communication, and resulted in steps to explore the space around our world. His extensive referencing provides the source materials, which describe the efforts of those early researchers, as they performed experiments and developed our theoretical understanding of electromagnetic wave propagation in the great out-door laboratory. The path of learning was not straight, as evidenced by the many false starts and incorrect paths described in this book. Students and scholars who study electromagnetic theory, and professors who teach it, would benefit from this historical review of the trials, successes, and failures during the first half of the 1900s. This history certainly drives home the fact that research means "trial" as the test of an idea, and the efforts to prove or disprove it. After my many years of ionospheric and upper atmosphere research, with experiments using rockets and satellites, as well as using ionosondes and incoherent scatter radar, and teaching a senior-level course on space physics and a graduate course on the ionosphere and upper atmosphere, I still learned many interesting things about the early developments of the field from Yeang's account. Many of the ideas tried by the early researchers, while making efforts to understand the mysteries of radio waves, were off the mark. However, their observations eventually led to the routine use of the radio, long-distance communications, and the discovery of the ionosphere. Also, I think this book offers a useful account of the trials and tribulations that all researchers face as they enter new research areas. We too often lose sight of this part of scientific discovery because textbooks and papers describe, and students are taught, the successful experiments and theories. Yet understanding nature often requires bringing together experimental results and theoretical models on a subject several times to get it right. Young researchers often do not realize that not every experiment or theoretical idea considered along the way actually answers questions asked by researchers, but each step contributes a small correction to the path which finally results in the textbook descriptions of today. It would be useful for young researchers in the physical sciences to read this book, just to see how the small and sometimes larger steps lead to understanding of a subject. The reading of this book is doubly recommended for any researcher who considers topics related to open-path communications, radar, ionospheric sounding, space physics, GPS technology, and electromagnetic waves in general.

This excellent book provides an interesting and useful account of the subject. The only addition I would have appreciated is a short chronology listing the contributors to and locations of landmark events between 1890 and 1950. Descriptions are presented in the context of the sequence of activities at a particular location, and hence, it is easy to lose sight of events occurring at other places that influenced activities at the location being described.

Russell Philbrick is a professor in the Physics and the Marine Earth and Atmospheric Science Departments at North Carolina State University, and is Professor Emeritus of Electrical Engineering at Pennsylvania State University. He did research in middle and upper atmospheric physics using mass spectrometers and accelerometers to study the composition and dynamics of the mesosphere, thermosphere, and the D-, E-, and F-regions of the ionosphere at the Air Force Cambridge Research Laboratories from the 1960s through the 1980s. Eight satellite instruments, several large coordinated rocket campaigns, and remote sensing techniques using ionosondes, radar, and lidar were developed and used for these investigations. His recent research has focused on the lower atmosphere with investigations using five generations of Raman lidar and DIAL lidar techniques to study the more complex properties of the lower atmosphere, with an emphasis on the optical properties of aerosols. At Pennsylvania State University (1988–2009), he enjoyed teaching upper atmosphere and ionosphere physics, remote sensing, and electro-optics, while working to encourage many excellent graduate students.

Electrons in Molecules: From Basic Principles to Molecular Electronics. Jean-Pierre Launay and Michel Verdaguer. 509 pp. Oxford U. P., Oxford, UK, 2014. Price: $89.95 (hardcover). ISBN 978-0-19-929778-8. (Gerald F. Thomas, Reviewer.)

In *Electrons in Molecules* (EIM), Launay and Verdaguer have provided us with a marvellous book reflecting their multidisciplinary knowledge of, contribution to, and perspective on current professional practice at the interface of physics, chemistry, and materials science.

Launay and Verdaguer spare us from the grandiose claim that an action principle of anyone's creation can be used to eponymously recover "electrons in molecules" in the manner others claim to have discovered "atoms in molecules." As a further bonus, their molecules are free from the propriety of having their electrons confined to envelopes of "zero-flux."

EIM's Preface states that the title "… can also be read as 'understanding the electronic structure and electronic properties of molecules.' Electrons are dividing their roles in a molecular entity: some ensure the chemical bonds and allow the stability of the molecules, while others are less bound to the atomic core and provide the molecules with their fancy properties—magnetic, electrical, photophysical, color, luminescence—allowing their use in molecular electronics, nanosciences, and so on…."

Unwittingly or otherwise, the book has the cyclical structure of Joyce's *Finnegans Wake* in that the final chapter (5) with "the electron mastered" returns to the first in revisiting the key concepts of symmetry and quantum mechanics that underlie "the localized electron," "the moving electron," and "the excited electron" in the corpus (2–4) covering the magnetic (2), electrical (3), and photophysical (4) properties of molecules, respectively.

The marketing description on the back cover claims that the book targets those students who would like a heads up on the field of molecular materials and devices. If it fails to inspire invention, it will succeed in revealing to them the wonders of molecular events at the most basic level and in instilling a less myopic viewpoint best reserved for courses that are more specialized.

The authors itemize EIM's unique features as including topic selectivity; emphasis on concepts over math; interdisciplinary appeal to students of physics, chemistry, and materials science; the premise that chemical synthesis provides the molecular objects best suited to the rational design of physics experiments; and the role of technique over paradigms as embodied in new technology and instrumentation that is replacing the molecular ensemble by the single molecule. Due to the first feature, dynamics is conspicuous in its omission. It is hard to imagine EIM being adopted as the basis of a course to be taught, although its approach could serve as a template for the design of a course better tailored to the experience and interests of the instructor. The book would benefit final year students contemplating graduate studies.

I found the most interesting chapter to be the one on molecular magnetism. Magnets are formed from metals, alloys, or oxides like magnetite, the first magnet discovered. Ever since, physicists have had most—but not all—of the fun. Linus Pauling's use of the relation between magnetic properties and the bonding of metal ions in complexes dating back to the early 1930s is legendary. So also is the Ising model of ferromagnetism, which represents magnetic dipole moments of atomic spins that can be in one of two states arranged on a lattice so that each spin interacts with its neighbors. The 2D square-lattice Ising model shows a phase transition; it was solved by the physical chemist Lars Onsager who subsequently won the Nobel Prize in Chemistry for unrelated genius. Chemists have been quietly working at low temperatures on using molecular chemistry techniques to develop new classes of magnets based on molecules rather than on metallic and ionic lattices. After reading EIM, however, I still do not know why there are no magnetic monopoles and it is unlikely that I will encounter a room temperature molecular magnet that will stick to the fridge like an old-fashioned magnet.

The main annoyance with EIM lays in its production, a responsibility of the publisher (OUP) and not of the authors. The book requires editing—not much, but enough (including the Index, which seems to have been automatically generated); the typesetting is ill-suited to formulas, making them look gauche and uncomfortable on the page due to a stilted style that keeps math from being italicized; and although the black-and-white figures are clear and informative in the print edition, many of them could do with a splash of color, at least in the eBook version if there is to be one. With a subtitle containing the unfortunate term "molecular electronics," EIM is cataloged to languish forever among the stacks for TK call numbers that chemistry and physics students tend to avoid, thus isolating it from its primary intended audience.

Gerald F. Thomas is a chemist. He recently retired as Principal Scientist/Engineer from MINOS Technologies, Inc., Toronto where he worked on a blend of theory and experiment in applied research. His interest in the emancipation of chemistry from physics is discussed in a recent paper in Foundations of Chemistry [Vol. 14, 109–155 (2012)].

BOOKS RECEIVED

The Six-Cornered Snowflake. Johannes Kepler. 89 pp. Oxford University Press, Oxford, UK, 2014. Price: $29.95 (paper) ISBN 978-0-19-871249-7.

Symmetries and Symmetry Breaking in Field Theory. P. Mitra. 111 pp. CRC Press, Boca Raton, FL, 2014. Price: $79.95 (hardcover) ISBN 978-1-4665-8104-3.

Physics Olympiad: Basic to Advanced Exercises. The Committee of Japan Physics Olympiad. 378 pp. World Scientific, Singapore, 2014. Price: $48 (paper) ISBN 978-9814556675.

Controlled Thermonuclear Fusion. Jean Louis Bobin. 238 pp. World Scientific, Singapore, 2014. Price: $68 (hardcover) ISBN 978-981-4590-68-6.

Spherical Harmonics in p Dimensions. Costas Efthimiou and Christopher Frye. 155 pp. World Scientific, Singapore, 2014. Price: $48 (hardcover) ISBN 978-9814596695.