Theory and Design of Charged Particle Beams

Martin Reiser
Wiley, New York, 1994. 607 pp. $64.95 hc ISBN 0-471-30616-9

Accelerated particle beams continue to find new applications in basic research, medicine and industry. From high energy and nuclear physics, the uses have branched out to synchrotron light sources, oil-well logging, dating of archaeological materials and many other areas. In addition, high-power beams have been proposed for energy production, high-level radioactive waste treatment and pulsed neutron generation. It is characteristic of most of these new applications that the quality of beam transport and manipulation is a concern at least as great as the technology and cost associated with acceleration.

The core material of *Theory and Design of Charged Particle Beams* by Martin Reiser concerns the fundamentals of beam transport by a system either of solenoids, or electrostatic or magnetic quadrupole lenses, or axisymmetric electrostatic lenses, starting with the Lorentz force law and Maxwell's equations. The emphasis is clearly on theory. The important role of space charge (and its neutralization) is incorporated into the transport model one-third of the way into the book, but it receives a very thorough treatment. The effect of a spread of particle velocities is treated at several levels of detail: the occupied phase space area (emittance), Maxwell–Boltzmann distribution and the Vlasov equation for the time-dependent distribution function in phase space.

Reiser is a professor at the University of Maryland and heads a research program on charged particle beam physics at its Institute for Plasma Research. His ongoing research, along with the graduate-level courses on beam physics he has taught for 30 years, forms the basis for this book. It is not intended as a text on particle accelerators, which are presented as applications that connect naturally to the main content; for example, material on periodic focusing is applied to the sector-focused cyclotron and strong-focused synchrotron. A wide variety of additional topics is covered briefly in a way that gives the reader the main ideas and some useful formulas. Examples are the treatment of beam cooling by the emission of synchrotron radiation and the application of Landau damping to beam stability in a storage ring. Often the minor topics arise from an interest in the growth or reduction of emittance by various physical processes.

This is a lengthy book with many interesting calculations and problems of the type one likes to work through in detail. However, it is not a complete guide for the design of a beam-transport system, because it does not treat vacuum, alignment, power supplies, magnet design, beam position monitors, computer control systems and so forth. Furthermore, beam-dynamics design for real systems generally receives a detailed treatment with a variety of codes whose description is outside the scope of this book. The formalism and concepts that underlie the numerical study of particle beams are the real content here, and as such they are of considerable value. The book will best serve physicists who are involved in beamline design and need to scope the beam parameters and phenomena at a preliminary stage.

The derivations are sound and detailed, but there is some misleading discussion. For example, it is indicated in section 2.3.4 that a particle with zero canonical angular momentum confined in a solenoid circulates at the Larmor frequency (ν_L). In fact it passes through the centerline where its phase jumps 180°, resulting in the physically expected circulation at the cyclotron frequency $\nu_C = 2\nu_L$.

Twenty years ago, the available general literature on charged particle beams was meager. This situation has changed dramatically, due in part to the US Particle Accelerator Schools, whose proceedings are published by the American Institute of Physics and now cover the field exhaustively. Within this background, *Theory and Design of Charged Particle Beams* provides a valuable in-depth derivation of principles that have application to many areas covered in the AIP series.

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The Music of the Heavens: Kepler's Harmonic Astronomy

Bruce Stephenson
Princeton U. P., Princeton, N. J. 1994. 260 pp. $39.50 hc ISBN 0-691-03439-7

Harmonices mundi libri V, or *Five Books of the Harmony of the World* (1619), has long occupied an uncomfortable position among Johannes Kepler's works. Although he probably considered the work his most profound contribution to human knowledge, the *Harmonices* has received scant attention. Indeed, if it did not

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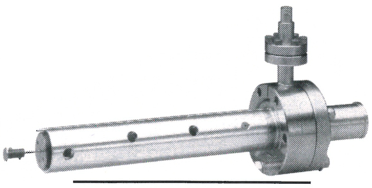

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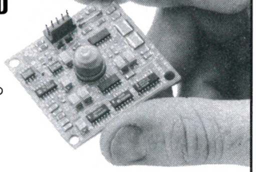

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contain the first statement of Kepler's third law, this unusual work might be virtually unknown.

Aware of its extreme difficulty, Kepler declared: "Let it wait a hundred years for its reader, as God himself has awaited a witness for six thousand years." Kepler has found at last a most capable reader in Bruce Stephenson. Coming from the success of his excellent *Kepler's Physical Astronomy* (Springer-Verlag, 1987), Stephenson now turns his patient, thorough analysis from the more familiar ground of Kepler's planetary theory to the alien territory of celestial harmony.

The notion that there actually are musical harmonies inherent in the spacing of the planets was a classical tradition. This idea of *musica mundana* passed through the Latin encyclopedists into the quadrivium (the four mathematical of the seven liberal arts, comprising arithmetic, music, geometry and astronomy), although it became recognized more by convention than by a lively tradition of research. Although the notion did not become entirely moribund—as a chapter on the work of Jofrancus Offusius illustrates—it found a particular resonance with Kepler, for whom the rational arrangement of the heavens was especially compelling.

Kepler treated the question of musical harmony as a corollary to the arrangement of nested polyhedra he presented in his *Mysterium cosmographicum* (1596). After a few succinct but complete introductory chapters, Stephenson accordingly begins with the *Mysterium*'s planetary distances. He follows Kepler's growing interest in musical harmonies after that work's publication, including his interesting reconstruction of three important lost chapters on planetary harmonies in Ptolemy's *Harmonics*. But Stephenson's treatment is rightly focused on Kepler's *Harmonices mundi*, especially book five.

Reconciling the distances, motions and eccentricities of the planets with the constraints of the polyhedral hypothesis and musical harmony in order to uncover the harmonic plan of the solar system was an extremely complex pursuit, through which Kepler persevered because of his great faith in God's rationality. Stephenson, with similar perserverance, leads the reader along the tortuous lines of Kepler's reasoning, and his attention and grasp of the material are rewarded with the discovery of several errors and inconsistencies in the *Harmonices* never noted before now. At the same time the reader experiences the tirelessness, genius and faith that were the hallmarks of Kepler's character.

Stephenson's book, and the tradition of *musica mundana* itself, effectively ends with Kepler's *Harmonices mundi*. One sees how Kepler's genius and fecund imagination so effectively exhausted the possibilities that he left few avenues for further development.

For serious students of Kepler's thought, this is an indispensable guide to an exquisitely Keplerian work, especially if read in conjunction with the first-ever full English translation of the *Harmonices mundi* (E.J. Aito, J.V. Field and A.M. Duncan translators, American Philosophical Society, in press). *The Music of the Heavens* is also accessible to nonspecialists who have some knowledge of 16th- and 17th-century astronomy and music theory.

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