phenomena, while . . . mathematical physics without experimental physics, would likewise be a rather lame and unfruitful science.

This attitude shaped Helmholtz's evaluations of candidates for university positions. Jungnickel and McCormmach consider Max Planck as the first true specialist in theoretical physics (in the sense that his career developed entirely in the subject). Yet Planck was considered by Helmholtz to be an "excellent acquisition" in replacing Kirchhoff as Berlin's theoretical physicist in 1889; Planck was a "splendid man" because his work was closely based on the experiments of others, on the interpretation and development of experimental measurements.

The main intellectual influence shaping German physics after 1870 was the work of James Clerk Maxwell. Helmholtz's influential treatment of electrodynamics and evaluation of the unique importance of Maxwell's electromagnetic theory of light encouraged the research of Heinrich Hertz, first under Helmholtz's direction at Berlin and then at Karlsruhe, which ultimately led to his decisive experimental test in favour of Maxwell's theory in 1888. As a visitor to Helmholtz's institute anxious to gain experience of experimental work, Ludwig Boltzmann undertook experiments (on dielectric constants) which bore on the confirmation of Maxwell's theory. In his research on the kinetic theory of gases and the entropy concept, Boltzmann extended Maxwell's law of the distribution of velocities among the molecules of gas, creating statistical thermodynamics. And in Leiden, Lorentz developed the "electron" theory which blended elements from German electrodynamics with Maxwell's theory of the electromagnetic field. The theoretical initiatives of Lorentz and Boltzmann, both much sought-after in German institutes of theoretical physics (Lorentz remaining in Leiden, but Boltzmann seeking to assuage his depression by moving to and fro between Graz, Vienna, Leipzig and Munich), encouraged German physicists to look to Maxwell's electromagnetic theory and molecular mechanics for their inspiration.

By the end of the century German physics, especially theoretical physics, manifested classical coherence and also innovatory thrust. The lectures of the classical masters Helmholtz and Kirchhoff summarized and codified the achievements of the past. The endeavours of Planck and Wien, debating the rationale of energetic and electromagnetic foundations for physics, opened the door to the new physics of quanta and relativity of the twentieth century, itself a creation of German theoretical physicists yet shaped by the problems which were perceived to flow from Maxwell's work. Planck came to exercise a formative influence, succeeding Kirchhoff in Berlin, and on Helmholtz's death becoming the advisor for theoretical physics for the *Annalen der Physik*. His research on blackbody radiation led him to introduce the quantum of energy, although he remained cautious about its implications. Nevertheless he was an early and influential supporter of Einstein's special theory of relativity.

Jungnickel and McCormmach conclude their account with an overview of the developments which arguably constitute the high point of German physics, the creation of the general relativity and quantum theories in the first quarter of the twentieth century. The authors emphasize the confluence of intellectual and institutional developments. Einstein came to the Prussian Academy and to Berlin in 1913 as the outstanding theoretical specialist, and soon delivered the "scientific eggs" in his general theory of relativity. The emerging generation of theoretical physicists, including Pauli and Heisenberg, received their education at the hands of men who had pursued careers as specialist mathematical physicists, Sommerfeld at Munich and Born at Göttingen. If classical physics had achieved its apotheosis in the lectures of Helmholtz and Kirchhoff, the new generation could build creatively on the shoulders of giants. The "now mighty theoretical physics", as Wilhelm Wien described it in 1915, had attained status as a "separate science". □

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Naked appreciation

P. W. Hawkes

Principles of Charged Particle Acceleration. By Stanley Humphries Jr. *Wiley: 1986. Pp.573. $65.95, £63.15.*

The difference between electron optics and the optics of charged particle acceleration is not unlike that between nudity and nakedness. It is possible to write a book on electron optics that sets out from a few premises and provides an elegant abstract description of the behaviour of electrons in the lenses, accelerating structures and analysers of which many instruments are composed. The typical example is P.A. Sturrock's *Static and Dynamic Electron Optics* (Cambridge University Press, 1955), in which it is not too fanciful to recognize the austerity of the classical nude.

In the optics of charged particle acceleration, on the other hand, the blemishes and homely imperfections of mere nakedness cannot be overlooked: many different kinds of particle may be present in the beam, the current density may be so high that the particles jostle one another in a way that renders the fundamental equations unmanageable, instabilities may set in and, in the great accelerators of recent years, even the irregularities of the underlying terrain cannot be neglected.

Stanley Humphries is well aware of the complexity of his subject matter and steers a middle course that accelerator physicists and engineers will be able to follow easily. Like Sir Thomas Browne, he believes that "where there is an obscurity too deep for our reason, 'tis good to sit down with a description, periphrasis or adumbration". He opens with concise accounts of particle dynamics in electric and magnetic fields, field calculation and materials properties. The next three chapters are concerned with lenses: round lenses, quadrupoles and sectors. Their effects on particle beams are first examined in terms of the elementary lens properties, after which the notions of acceptance and matching are introduced. The last of these chapters explains the transfer matrix formalism. Humphries does not go far into these optical matters, but this merely emphasizes that he has written a book on acceleration and has included only the necessary minimum about them.

Apart from a single chapter on the difficult theme of phase dynamics, the rest of the book offers a detailed and knowledgeable account of the various types of accelerator. Electrostatic accelerators and pulsed high-voltage, linear-induction accelerators, betatrons, radiofrequency accelerators and, finally, cyclotrons and synchrotrons: each of these is accorded a separate chapter, as are the resonant cavities and waveguides employed. Not only are the modes of action of the various machines clearly described, but the book is also a rich hoard of down-to-earth engineering detail that will make it used and appreciated far beyond the introductory course on the physics of charged particle acceleration that inspired it.

Humphries has brought together and successfully organized a mass of material in the first large single text to be devoted to his subject since *Linear Accelerators,* a multi-author work edited by P.M. Lapostolle and A. Septier and published by North-Holland in 1970. I suspect that many readers will need to go elsewhere to delve into the subjects of the earlier chapters in more detail, but they will surely forgive the author for preferring to save his space for the accelerators themselves. Altogether, this is an impressive and consummately useful volume. □

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