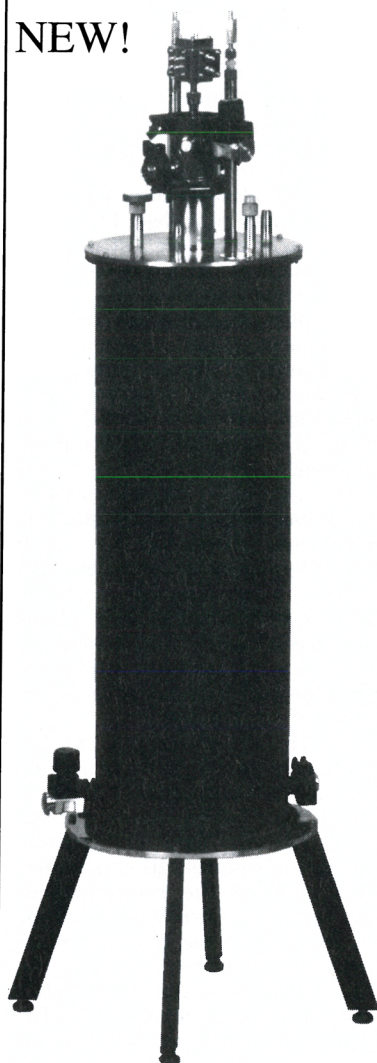


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World War II once again made him interact strongly with his scientific colleagues. In the early 1930s, Dirac had been interested in the separation of isotopes by the centrifugal effect. His research at that time included the design and construction of apparatus. With the encouragement of Peter Kapitza, Dirac carried out the experimental work himself. He returned to these problems during the war and made important contributions to the separation of uranium isotopes and to gas centrifuge technology in general.

After the war, he became a loner once again, marching to the tune of his own drum. The "inadequacies" of quantum field theory became a constant refrain, and on many occasions he explained why he was not satisfied with the renormalization program, even though it was "a big success": He felt that physicists should concentrate on trying to find "the correct Hamiltonian."

Science is a social process and the consequences of isolation are strikingly apparent in the cases of men of genius like Dirac and Einstein.

A Journey into Gravity and Spacetime

John Archibald Wheeler

Freeman, New York, 1990.

257 pp. \$32.95 hc

ISBN 0-7167-5016-3

G. D. Birkhoff is reputed to have said that any intelligent 12 year old can understand general relativity—provided he or she is familiar with tensor analysis. In this remarkable book John Archibald Wheeler sets out to explain the central ideas of general relativity to readers whose previous acquaintance with mathematics stops at elementary algebra. His strategy is not to skirt the difficulties of tensor analysis but to dig beneath them. In his 1973 graduate text *Gravitation*, written with Charles W. Misner and Kip S. Thorne, Wheeler introduced a generation of physics students to Elie Cartan's coordinate-free approach to differential geometry and general relativity. Cartan's language of differential forms, wedge products and exterior derivatives is more abstract than tensor analysis, but in certain respects it is also simpler. In *A Journey into Gravity and Spacetime*, Wheeler undertakes the monumental task of translating key aspects of Cartan's version of Einstein's theory into words and pictures.

Some aspects of Einstein's theory lend themselves readily to a pictorial-verbal approach—for example, the notions of curved space and curved

space-time, and of geodesics and geodesic deviation. But Wheeler isn't content to stop here. His far more ambitious aim is to make intelligible to nonmathematical readers what he regards as the heart of Einstein's theory, the contracted Bianchi identity. Cartan showed that this identity follows from a principle that Wheeler sums up as "the boundary of a boundary is zero," and that it expresses the conservation of a geometric object, the moment of rotation. Einstein's field equation makes this geometric object proportional to momentum-energy, which has the same symmetry characteristics, thereby ensuring that momentum and energy are conserved. "Thus simply," Wheeler and his coauthors wrote in *Gravitation*, "is all of general relativity tied to the principle that the boundary of a boundary is zero." In his new book Wheeler seeks to elucidate "the double grip of mass on spacetime and of spacetime on mass" by guiding the mathematically naive reader along the path that leads to this conclusion.

Having secured this primary objective, Wheeler next builds up a detailed picture of the curvature of space and space-time in the vicinity of a center of mass. In this context he introduces the reader, gently but firmly, to some basic notions of differential calculus. A partial derivation of the Schwarzschild metric paves the way for a clear account of particle orbits near a black hole, based on the angular-momentum and energy integrals of the exact equations of motion. There follow insightful but less detailed accounts of black-hole thermodynamics and gravitational radiation.

In a short final section on cosmology, Wheeler attacks several pillars of contemporary conventional wisdom. He concludes that the nonluminous component of galaxies and galaxy clusters is ordinary matter rather than some hypothetical kind of non-nucleonic matter (for example, "cold dark matter") and that gravitation alone is responsible for both the large-scale structure of the universe (filaments and voids) and hierarchical gravitational clustering. He also states that the fact that the present cosmic mass density is not greatly different from the value corresponding to zero spatial curvature requires no "fine-tuning of the initial expansion rate" and no "new principle that will automatically guarantee the desired delicacy of adjustment of the energy." I agree with these heterodox conclusions but not with some of the arguments used to support them. For example, given Wheeler's assumptions, the cosmological model he de-

BOOKS

scribes would contain far more primordial helium than astronomical observations allow.

The text abounds in visual images, which come to life in lavishly detailed and aesthetically pleasing diagrams whose captions illustrate the maxim that a good picture deserves a thousand words. Concrete visual details serve to anchor abstract ideas: Matchsticks representing radii of curvature have heads, matter and space-time grip one another with pairs of hands, the "energy hill" of a particle near a black hole is made of plaster of Paris. The diagrams are supplemented by beautifully executed full-color drawings and well-chosen photographs. The overall visual effect is stunning.

Like Wheeler's earlier books, *A Journey into Gravity and Spacetime* makes liberal use of parables, stories, imaginary conversations, dreams and visions, neologisms ("momenergy"), slogans ("law without law"), magnifying glasses, film strips, time-lapse sequences and sentence constructions that encourage participatory reading. There is also a good deal of free verse. Each chapter opens with a poem in exalted style, and there is a long prefatory ode whose final stanza summarizes the book's central message:

*Help me to make this account
A radiant testimony
To the wonderful simplicity
Of the principle that the boundary
of a boundary is zero,
Heart of Einstein's great 1915,
Battle-tested, and still standard
Geometric account of your action,
oh Gravity.*

DAVID LAYZER
Harvard University

Elementary Particle Physics: Concepts and Phenomena

Otto Nachtmann
Springer-Verlag, New York,
1990 [1985]. 559 pp.
\$98.00 hc ISBN 0-387-50496-6

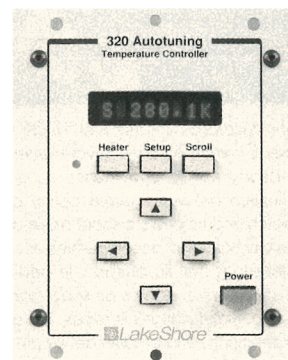
Otto Nachtmann's book is a new entry in the growing list of introductory particle physics texts for the post-"standard model" era. It looks like a good one, although I should point out that I have not given this book the ultimate test in the classroom: Most of us have had the experience of seeing diamonds lose their glitter as the semester progresses. The text is a translation from the original German edition, which has been around for about five

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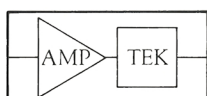
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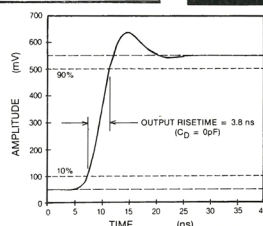
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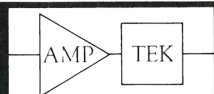
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