Three Roads to Quantum Gravity

Lee Smolin
Basic Books, New York, 2001. $24.00 (231 pp.). ISBN 0-465-07835-4

The 20th century witnessed two conceptual revolutions in physics; these in turn led to the most successful physical theories ever: general relativity and quantum mechanics. Immediately after their creation Oskar Klein in 1927 suggested that quantum mechanics should be applied to general relativity, and technical papers on the subject were written by Matvei Bronstein, Léon Rosenfeld, Wolfgang Pauli, Markus Fierz, Werner Heisenberg and others. These early investigations already suggested that something would go seriously wrong in this endeavor.

The difficulties did not go away when Peter Bergmann, P. A. M. Dirac, Richard Feynman and Bryce DeWitt applied the modern tools of quantum field theory to the problem in the 1950s and 60s. Since then, many people have considered the question to be one of the main outstanding conceptual issues in fundamental physics. Some feel that solving it will require another major revolution, akin to those that created relativity and quantum mechanics themselves. But that revolution has not happened yet! It is therefore not entirely surprising that this field of research is experiencing a sort of conceptual disarray, with several groups of researchers trying various avenues of approach to the problem. Lee Smolin's *Three Roads to Quantum Gravity* attempts to provide a picture of the situation "from the frontline."

Smolin divides the field's research avenues into three. One is string theory. The community of physicists working in string theory has its roots in particle physics and perceives the problem of quantizing gravity as trying to find a theory of gravity other than general relativity that will fit better with the rules of quantum mechanics and that in turn will unify all interactions. String theories normally live in dimensions higher than four, and getting results in four dimensions is one of the challenges.

As an approach, string theory has achieved many successful results, and is covered by several books accessible to the general public. The number of physicists working on string theory is large, making it the "majority viewpoint" with respect to quantum gravity.

The second avenue to quantum gravity is an approach broadly known as "quantum geometry." People working with this approach tend to believe that it has not been convincingly shown that unsolvable problems exist in the quantization of general relativity. Rather, they believe that people have not been careful enough with the process. After all, the theory of quantum geometry clearly has several unique features, since it is a theory of space-time itself rather than a theory of a field living in space-time—which would make its quantization unusually tricky.

One of the cornerstones of the quantum-geometry strategy is to use sophisticated mathematical tools to understand the space of quantum states of the theory. The approach was first taken when Abhay Ashtekar found a reformulation of Albert Einstein's theory that resembles a Yang–Mills theory. This has allowed the use of techniques from particle physics, appropriately extended, to define for the first time mathematically consistent theories of quantum gravity without divergences. People working with quantum geometry want to understand the quantization of Einstein's traditional general relativity in four space-time dimensions (rather than string—or another—theory), and believe that the unification of forces is a separate problem, to be tackled later.

The number of researchers taking this tack is considerably smaller than those in string theory and generally come from research groups that study classical general relativity rather than particle physics.

The third route consists of a variety of almost unipersonal efforts, by single investigators or very small groups, that are based on more radical points of view, points of view that sometimes imply modifications of both general relativity and quantum mechanics, or even their mathematical foundations. In spite of their small following, these efforts tend to be spearheaded by individuals who are highly respected and who have been remarkably insightful in their previous contributions in physics.

Smolin's book is unique in that, to my knowledge, there are no books or articles accessible to the general public that cover the second and third approaches. In parallel, Smolin also incorporates a bit of introspection—discussion of his own role in all this. This is interesting since, although he is a major contributor to the quantum-geometry strategy, he has always sought connections with the other approaches. The book is sprinkled with nice personal anecdotes as it describes the development of quantum geometry from a historical perspective. What emerges is an intimate look at the development of the field.

The book is lively reading. It is oriented to a general, educated readership. A book like this, which covers minority viewpoints, will inevitably receive criticism. Some colleagues have said it is not deep enough. I disagree. The book is a report, it is not necessarily intended to advance a new point of view. Smolin also acknowledges up front that the coverage is subjective. It is a pity that the book could not cover recent claims that experimental effects of quantum gravity may be observable. The field would definitely change in nature if it acquired a phenomenology to explain.

I strongly recommend this book to people interested in keeping up with this active intellectual frontier.

Jorge Pullin
Louisiana State University
Baton Rouge

Physics for Radiation Protection

James E. Martin
Wiley, New York, 2000. $150.00 (713 pp.). ISBN 0-471-35373-6

Permissible Dose: A History of Radiation Protection in the Twentieth Century

J. Samuel Walker
U. of California Press, Los Angeles, 2000. $35.00 (180 pp.). ISBN 0-520-22328-4

A reader comes to James E. Martin's *Physics for Radiation Protection* aware of its author's considerable reputation; in his half-century career he has trained many hundreds of students at the University of Michigan and written many influential and informative works. As stated in the preface, this book "is intended to be a text of basic physics concepts that health physicists and other radiation protection specialists need, presented at a level that can be understood by people with limited science background." When viewed in that limited context, the book appears to do its job; given the author's significant reputation in radiation health physics and teaching, this is no surprise.