

number of decay modes, would lead to a deeper understanding of the so-called Standard Model of elementary particle physics. Such a breakthrough might have come from a deviation between measurements and weak-interaction theory's predictions of the measured properties of purely leptonic decay modes. Or it might have come from unexplained measurements in the tau decays to hadrons. But so far, there have been no confirmed deviations and no unexplained results in the many hundreds of measurements of the behavior of the tau lepton.

Yet hope for discovery is one of the important strengths of science, and Achim Stahl's beautifully written and comprehensive book, *Physics with Tau Leptons*, comes at a most opportune time for tau physics. (Stahl is a member of the physics faculty at the University of Bonn and a scientific associate at CERN.) Three new electron-positron collider sources of tau leptons are now beginning operation: CESR III (Cornell Electron Storage Rings III) and PEP II in the United States, and KEK-B in Japan. These colliders will make greatly increased numbers of tau decays available for study, and the improved experiments will yield improved measurement quality. *Physics with Tau Leptons* provides a firm basis in theory, in measurement techniques, and in summaries of known results for making full use of these improvements in quantity and quality of data on the tau. The book will be useful for younger researchers in the field, who don't know the history of the hundreds of tau measurements, as well as for older researchers who have forgotten that history.

The book begins with a bit about the discovery of the tau followed by a very useful general chapter on experimental techniques in tau physics. The following eight chapters are devoted to different areas of tau physics, ranging from static properties of the tau and strong-interaction physics in tau decays, to the tau neutrino, and to searches for CP violation in tau decay. Each of these chapters contains a skillful merger of the theory in the area and summaries of the main experimental results. For example, the chapter on the structure of the weak charged current begins with the general theory of that current restricted only by principles such as Lorentz invariance. It then shows how the combination of observations and more detailed theory reduces to the currently accepted V-A current. Present measurements relevant to the nature

of the current are summarized, and then the reader is shown where experimental searches for deviations from the standard model may still be possible.

The book will also be interesting and useful to those who work on the physics of the electron, the muon, or their neutrinos, as well as for those who are searching for heavier leptons. *Physics with Tau Leptons* belongs in the physics libraries of all universities and research laboratories. Those who have it in their personal libraries will treasure its comprehensiveness and clarity.

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Black Hole Physics: Basic Concepts and New Developments

Valeri P. Frolov
and Igor D. Novikov
Kluwer Academic, Norwell, Mass.,
1998. 770 pp. \$320.00 hc
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Black holes have been around for a long time. Indeed, the rough concept of an object that is so dense that even light cannot escape to be seen by a distant observer is over two hundred years old. (John Michel introduced the idea in 1784, within the context of newtonian gravity.) As well, the most basic general relativistic black hole model solution was found by Karl Schwarzschild almost eighty-five years ago (within just a few months of the 1915 paper in which Albert Einstein introduced his new theory of gravity and general relativity).

Yet as recently as the early 1960s, very little was known about rotating black holes, about astrophysical processes that might lead to the formation of a black hole, or about the behavior of particles and fields near black holes. Ten years later, although the name "black hole" (coined by John Wheeler in 1967) had made its way into the popular culture, the black hole was still viewed by most physicists as a rather exotic construct of general relativity with little if any role to play in the physical universe.

Today, things have changed dramatically. Very few dispute the observational evidence for the presence of massive black holes at the center of many (if not most) galaxies, and the role that these supermassive black holes (with masses between 10^6 and

10^8 times that of the sun) play in galactic astrophysics seems to be a very important one. The evidence for solar-mass sized black holes is almost as compelling.

Thus there is a clear need for an up-to-date text that carefully and comprehensively explains the physics of black holes to physicists. To a large extent, Valeri Frolov and Igor Novikov's book *Black Hole Physics* serves this purpose.

This is not an introductory text in general relativity. For that, the reader is directed to either Robert Wald's comprehensive *General Relativity* (Chicago, 1984), or to Bernard Schutz's more introductory *A First Course in General Relativity* (Cambridge, 1985). Nor is *Black Hole Physics* either a mathematically precise treatise on black holes or a popular discussion of them. For mathematical precision, the reader should consider S. Chandrasekhar's *The Mathematical Theory of Black Holes* (Clarendon, 1983), or *The Large-Scale Structure of Spacetime* (Cambridge, 1973) by Stephen Hawking and George Ellis. For a popular treatment, I recommend Kip Thorne's *Black Holes and Time Warps* (Norton, 1994).

What Frolov and Novikov's book does is present a relatively clear, encyclopedic discussion of a very large number of topics related to the physics of black holes. The book is a very much expanded and updated edition of the authors' 1989 volume, and its range is impressive. It discusses the orbits of particles and the behavior of electromagnetic and other fields around both Schwarzschild (spherically symmetric) and Kerr (axially symmetric) black holes, and it relates these results to what an observer might see if a black hole were present. It sets up some of the basics for understanding the properties of black-hole event horizons, apparent horizons, and trapped surfaces, and it uses some of these ideas to suggest the flavor of the singularity theorems and what cosmic censorship is all about. The book presents an especially extensive discussion of the Hawking radiation and quantum particle creation properties of black holes, and it covers black hole thermodynamics in impressive detail.

In view of the wide range of topics that the book covers, one cannot expect a detailed treatment of all of them. In most cases, however, Frolov and Novikov provide at least a good overview, as well as a very detailed collection of references. This works well, for example, in their treatment

of black-hole perturbations: they explain the basic ideas and present some of the key equations that must be handled, and then they refer the reader to the very comprehensive work of Chandrasekhar and others, together with some of the original papers of Tulio Regge, John Wheeler, and Frank Zerilli.

Though I am generally pleased with the range of topics covered by the book and the depth of coverage for many of them, I do wish the authors had discussed one particular topic quite a bit more: With gravitational radiation data expected to start coming in during the next four to six years from LIGO (Laser Interferometer Gravitational Observatory), and from its European counterpart, VIRGO, there is now a very strong and timely interest in understanding more about the amount and nature of gravitational radiation that present theory predicts should be produced by interacting black holes. Most of the studies directed toward that understanding are numerical and are based on the 3+1 dynamical analysis of solutions of Einstein's equation. *Black Hole Physics*, unfortunately, says almost nothing about the 3+1 approach and very little about the dynamics of closely interacting black holes.

I have two other minor complaints, neither of which would be hard to fix. The first is that the index is inadequate. A comprehensive, wide-ranging book like this would benefit greatly from a good index. Indeed, there are a number of topics—for example, the ADM (Arnowitt–Deser–Misner) mass, the Penrose area/mass inequality, and the role of the cosmological constant—that are unmentioned in the index but are discussed in *Black Hole Physics*. My other complaint concerns the price. I think this book would be a valuable resource for many graduate students, but the price—\$320—would probably prevent them from buying it.

Forgetting the price, I do recommend *Black Hole Physics* to any graduate student or researcher with a grounding in general relativity and an interest in gravitational physics or astrophysics. Black holes play an important role in the physics of the universe; the need to understand them will almost certainly continue to grow, and Frolov and Novikov's book does a very good job in explaining what we know about them today.

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ENIAC: The Triumphs and Tragedies of the World's First Computer

▶ Scott McCartney
Walker and Co., New York, 1999.
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Many people believe that the computer was the greatest invention of the twentieth century. Because it has made the information revolution possible, knowledge of its genesis is important. *ENIAC*, written by Scott McCartney, a journalist, succeeds in illuminating a crucial corner of this genesis. The book falls naturally into the sequence of such computer-related books as Tracy Kidder's *The Soul of a New Machine* (Little Brown, 1981), and Charles J. Murray's *The Supermen: The Story of Seymour Cray and the Technical Wizards behind the Supercomputer* (Wiley, 1997). But rather than dealing with latter-day computer developments as the other books did, McCartney's book deals with the ENIAC (Electronic Numerical Integrator and Computer), characterized by the author as the first digital general-purpose electronic computer. The book tells an engrossing story of achievement, betrayal, and cooperation, one that has its quota of both knavish and unselfish behavior. Emphasis is more on personalities and credit assignment than on scientific and engineering problems.

This book tells four stories:

1) The author describes the conception and the construction of ENIAC at the Moore School of the University of Pennsylvania. The heroes of the story are Presper Eckert and John Mauchly, the inventors and principal designers of ENIAC. Eckert, a creative electrical engineer, was only 24 years old when he and Mauchly began work on the ENIAC in 1943. Eckert first proposed the concept of a stored-program computer in 1944, surprising news to many who believe that John von Neumann originated this crucial computer-architecture idea. John Mauchly was a tenacious, introspective physicist, twelve years older than Eckert. As early as 1939, he was planning to build an electronic calculating machine using vacuum tubes, and he was aware of the use of relays for digital calculations. In 1942, while teaching at the Moore School, Mauchly wrote a seven-page proposal entitled "The Use of High-Speed Vacuum Tube Devices for Cal-

culatation." Thanks to the initiative of Herman Goldstine, a young army officer at the Ballistics Research Laboratory, Mauchly's proposal was funded in 1943, and work on the ENIAC began.

Remarkably, by the middle of 1944, the first units of ENIAC were operational, and the machine was fully completed by the fall of 1945, too late to be needed for its original purpose: the calculation of gun-firing tables. It was soon put to use, however, on nuclear-weapons calculations. It is important to emphasize that ENIAC did not include a stored program, and it was not until the second Eckert–Mauchly machine, the EDVAC (Electronic Discrete Variable Calculator), that this crucial feature was included in the design.

2) The story is told of how, when it was clear that ENIAC was a success, others sought the credit. The book suggests that the first of these was Grist Brainerd, the chief administrator of the ENIAC project, who unsuccessfully tried in 1945 to become sole author of an important report on the machine and to keep Mauchly from attending a significant computer-related meeting.

Both Herman Goldstine and John von Neumann consulted with the ENIAC team and were thoroughly familiar with its designs and with Eckert and Mauchly's plans for the EDVAC, which was to use Eckert's mercury delay line as internal memory for a stored program. In 1945, von Neumann wrote a "First Draft of a Report on the EDVAC," which summarized a large body of work done by others, including the stored-program concept, yet listed only von Neumann as author. This report, considered to be an internal document, was nevertheless widely distributed by Goldstine, thus co-opting for von Neumann the credit for both the ENIAC and the idea of the stored-program computer. While von Neumann never explicitly claimed credit for the idea of stored-program computer architecture, he never publicly conceded that the ideas in the "First Draft" were not entirely his. This report and the 48 "Moore School Lectures," given by Mauchly, Eckert and many others, and which are discussed in the book, led to wide dissemination of computer design technology at a very early stage of computer development and resulted in the first operating stored-program computer: the EDSAC, built in 1949 by Maurice Wilkes, David J. Wheeler, and Stanley Gill of Cambridge University, not the EDVAC.

3) Eckert and Mauchly's launching