of his book appears as a *gedanken* experiment, and even though it is heavy going and at first glance redundant, it merits close attention by literate technologists as well as nontechnologists who are broadly educated and have wide interests.

Both authors try to deal with the insane matter of deterrence policies. Let them speak. Zuckerman:

> According to the O.E.D., to deter means "to restrain from acting or proceeding by any consideration of danger or trouble." ... In the popular mind, however ... the word "deterrent" today means a nuclear weapon .... [A] sane government will be deterred from embarking on hostile acts against another country if, in its judgment, such action would entail either a certain or a significant risk that its own people, its economy and its apparatus of state control, would suffer disproportionately more than would be justified by the value of whatever prizes victory might bring. It is axiomatic that no sane government would initiate or permit acts which, in its opinion, might escalate to a level that would trigger "unacceptable" nuclear retaliation.

Schell:

> The central proposition of the deterrence doctrine—the piece of logic on which the world theoretically depends to see the sun rise tomorrow—is that a nuclear holocaust can best be prevented if each nuclear power, or bloc of powers, holds in readiness a nuclear force with which it "credibly" threatens to destroy the entire society of any attacker, even after suffering the worst possible "first strike" that the attacker can launch. Robert McNamara, who served as Secretary of Defense under Presidents Kennedy and Johnson, defined the policy, in his book *The Essence of Security*, published in 1968, in the following terms: "Assured destruction is the very essence of the whole deterrence concept. We must possess an actual assured-destruction capability, and that capability also must be credible. The point is that a potential aggressor must believe that our assured-destruction capability is in fact actual, and that our will to use it in retaliation to an attack is in fact unwavering." Thus, deterrence means the certainty of suicide to the aggressor, not merely to his military forces, but to his society as a whole.

These ideas should not be difficult to understand. George A. Miller, in his book *Spontaneous Apprentices*, about language learning by small children, devotes a page to the following game between two 4-year-olds:

> **Girl** (on play telephone): David!
> **Boy** (not picking up other phone): I'm not home.
> **Girl:** When you'll be back?
> **Boy:** I'm not here already.
> **Girl:** But *when you'll be back*?
> **Boy:** Don't you know if I'm gone already, I went *before* so I can't talk to you!

This does not imply that every child can understand such logical subtleties, but people who are elected or appointed as national leaders should be able to carry the logic lines that some four-year-olds can.

In a chapter entitled "Fighting with Nuclear Weapons," Lord Zuckerman completely demolishes the notion that wars waged with nuclear weapons can be anything but outrageous and that "predictions" can be anything but guesses. For instance, two sentences show the kind of detail one can find in his book:

> In one war game in which it was assumed that only the defending British forces used nuclear weapons, but in which the Russians for some reason or other refrained from using them, the detonation of sixty nuclear weapons ... still failed to prevent the Russians from crossing the River Weser in force. [The Russians] were, however, held in another war game, in which [they] again did not fire nuclear weapons but ... our troops used 130 nuclear weapons.

The easiest way to summarize all of this is to quote from the introduction to Lord Zuckerman's book:

> The central facts are merely lost in technicalities. What matters is that a nuclear exchange could blot out civilization in both the Eurasiatic and North American continents; that nuclear warheads are too dangerous to use in war; and that while nuclear weapon states might be deterred from turning their nuclear arsenals on each other, the existence of nuclear weapons can neither prevent war nor defend in war.

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Above, the typical spur-and-gully wall morphology (butte is 20 km wide) in the lower Kasei Vallis canyon of Mars; at right, a residual loess hill (1 km wide) streamlined by flood erosion in the scabland of Washington state. These images illustrate Victor R. Baker's hypothesis, in *The Channels of Mars* (198 pp. U. of Texas P., Austin, 1982. $39.95) that catastrophic flooding cut through the now arid Martian surface to produce some of the largest channels in a manner similar to the way Pleistocene flooding formed the scablands of the Columbia plateau.

Theory and Experiment in Gravitational Physics

C. Will

341 pp. Cambridge U. P., New York, 1981. $75.00

The apparent incompatibility between the Newtonian conception of gravity and special relativity, rather than direct experimental evidence, led Albert Einstein to formulate the general theory of relativity. In his original papers, Einstein proposed three experimental tests: Mercury's perihelion shift, gravitational red shift, and light deflection by the Sun. Einstein demonstrated that general relativity agrees with the—by then known—perihelion shift. The second test, the red-shift experiment, demanded technological sophistication not available during the first half of this century and had to wait until the early sixties. Arthur Eddington's confirmation of the third prediction, the light deflection, led to the dramatic acceptance of general relativity.

In spite of the newspapers' headlines, Eddington's observation as well as the perihelion shift (and, in fact, most of the current observations) only test some weak-field limit of general relativity. The uncertainty in Eddington's observations and the lack of conclusive observational evidence for strong fields has motivated many researchers to propose alternative gravitational theories. By now a few dozen such theories exist. In the early days a lack of observational data left a large margin for alternative theories. Similarly, a lack of computational tools led to proposals of theories whose predictions disagreed with existing data, the computations being too cumbersome to reveal inconsistencies.

In *Theory and Experiments in Gravitational Physics*, Clifford Will describes how this situation has drastically changed in the last 20 years. Technological advances have led to tighter limits on the old experiments and to new tests, some of which involve the most precise measurements ever made in physics. On the other hand, new theoretical formalisms, such as the parametric-post-Newtonian formalism, provide computational and conceptual tools for comparison of gravitational theories and experiments. Will, who contributed extensively to the theoretical developments in this field, describes the new confrontation between experiment and gravitational theory, which apparently leaves only general relativity and five other theories surviving.

The task of confronting theories with observations is fairly limited if one restricts oneself to existing theories or extremely ambitious if one wishes to include all possible theories. In the latter case one has to develop a theory of theories that should include all possible theories, including ones that have not yet been explicitly conceived, as well as (of course) the "real one." Will aims for the more ambitious goal in this book. He begins by a discussion of the Dicke framework. Examining the experimental evidence for the equivalence principle, he concludes that any theory of gravitation must be a metric theory. He proceeds with an extensive discussion of the parametric post-Newtonian formalism and its application to about a dozen gravitational theories and a half-dozen experiments. In the following section he describes the E(2) formalism for classification of gravitational theories according to the gravitational radiation that they contain (a purely theoretical discussion, of course, as gravitational radiation has not yet been detected). The rest of the book considers the structure of black holes and compact objects, the binary pulsar, and the implications of other cosmological matters on gravitational theories.

Although I enjoyed reading the book, I felt that the author emphasized the parametric post-Newtonian formalism at the expense of other topics. I would have liked to see a more detailed discussion of the experiments themselves. Will usually refers the reader to the original papers for such a discussion—an extensive reference list is indeed available—which I believe does not do justice to the book's title. After all, the same experiment may lead to a different conclusion when considered from the point of view of a radically different theory.

The validity of the Newtonian limit is another topic that deserves more detailed exposition. After he devotes one paragraph to the experimental status of Newtonian gravitation, Will stresses that all gravitation theories should yield Newtonian gravity as a limit. Considering the important impact of this restriction, one would desire a more careful discussion of the observational evidence supporting Newtonian gravity. After all, the inverse square law of gravity has been verified experimentally only in the range from a few centimeters to a few astronomical units; even within this range the question whether G is really a constant is not completely settled.

A potential danger in any text covering a large field is that the basic physical picture will be obscured by the fine details. Will avoids this danger successfully in the first chapter of the book in which he describes the Dicke framework. Unfortunately the connection between experiment and basic physical concepts becomes less clear in later chapters of the book, which overwhelm the reader with technical details.

After I read the book, curious colleagues asked me how well do general relativity and alternative theories pass the experimental tests. As is well known, general relativity passes all current tests with flying colors. Had there been a contradiction, we would have heard about it (probably prematurely) from the (front?) pages of *The New York Times*. The author shows that restricted versions of five competing theories (scalar–tensor, Will–Nordtvedt, Hellings–Nordtvedt, Rosen, and Rastall) pass all solar-system tests. However, the complete answer is left as an exercise to the reader. An additional chapter examining the experimental status of *all* current theories of gravitation and giving a complete up-to-date answer to this question would have served well as a conclusion for the book.

In spite of these few shortcomings, the experienced reader will benefit from this book. I can definitely recommend it as an extensive source of valuable information to anyone who wishes to become familiar with the "tools of the trade" in this field. It will enable researchers interested in new alternative theories to general relativity to make clear and immediate comparisons of new theories to existing experiments. To researchers contemplating new gravitational experiments, the book will provide useful guidance in considering the implications of their measurements on the verification of general relativity and competing theories, provided, of course, that they can afford the unusually high price ($75) of the book.

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Methods of Statistical Physics

A. I. Akhiezer and S. V. Peletminskii
448 pp., Pergamon, New York, 1981. $54.00

Statistical mechanics is a field of sharp dichotomies, in which few attempts are made to strike a balance. Some writers show an exclusive preoccupation with minutiae of mathematical rigor to the neglect of physical considerations; others do the opposite. The same imbalances exist with regard to principles vs. applications, Boltzmannian distribution functions vs. Gibbsian canonical ensembles, stochastic models vs. correlation functions, philosophical interpretation vs. pragmatic prediction, and so on.

As noted in a foreword by N. N. Bogoliubov, *Methods of Statistical Physics* is unique in that the authors try to balance these many extremes. In my opinion, while they come closer than anyone else in accomplishing this, they miss a point of basic understanding needed to bridge the most fundamental dichotomy.

The many applications have a neat and elegant quality. As one would expect from other well-known works of A. I. Akhiezer, the treatment of macroscopic electrodynamics is particularly thorough. The derivation of macroscopic hydrodynamics extracts a surprising amount of information from Galilean invariance; some of the special properties of superfluids are then seen to result from failure of Galilean invariance. The Wigner distribution function, hitherto a rather mysterious and unwieldy item defined on the $6N$-dimensional phase space, becomes—by use of quantized wave functions—a Wigner distribution operator in ordinary position–velocity space, a much simpler and more useful quantity.

The applications are so interesting, useful and well presented that it is a temptation to concentrate entirely on