el, but also because such a mass neatly closes the universe and prevents indefinite expansion. At about the same time, an experiment at the Savannah River reactor gave indications of neutrino oscillations, which can only occur if at least one type of neutrino has mass. In addition, Ray Davis (Brookhaven National Laboratory) was not seeing the expected number of electron neutrinos from the Sun, another possible manifestation of neutrino oscillation and mass.

So the race began in earnest, with new experiments on tritium beta decay, on neutrino oscillations at reactors and accelerators, and on neutrinoless double beta decay (which, oddly enough, tells you something about neutrinos). None of the dozen new tritium experiments has yet been able to confirm or contradict the ITEP claim (down now to 26 eV) with absolute conviction. The original Savannah River result has long since been repudiated, in part by the oscillation experiment mounted by Boehm and Rudolf Mössbauer at the Gösgen reactor in Switzerland. Another oscillation experiment, at the Bugey reactor in France, appeared to give new evidence for oscillations, but that result too has been withdrawn (since the publication of *Physics of Massive Neutrinos*). Accelerator experiments from time to time have shown tantalizing but not uncontradicted hints of oscillations. Kinematic experiments on the μ and τ neutrinos have never shown any indication of mass, and the limits have been progressing steadily downward.

To be sure, there are a few minor errors (the neutrino threshold on He^3 is 1.04, not 0.52, MeV), but in general the book is thoroughly researched and very comprehensive. *Physics of Massive Neutrinos* is much more than a snapshot of a field in transition, with limited long-term value. Intended for specialists, it is a compendium of the methods and theoretical underpinnings of neutrino physics, and will likely become the handbook of practicing neutrino physicists everywhere.

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Theory of Multiphoton Processes

Farhad H. M. Faisal
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The behavior of atoms and molecules subjected to intense electromagnetic fields at optical and infrared frequencies has become a major field of investigation. Developments in laser instrumentation allow the experimenter to deliver large amounts of energy into small volumes during short time intervals. Technological developments have led to an extraordinary enhancement in spectral resolution, and spectroscopic experiments have yielded data of unprecedented precision on the energy-level structures of atomic and molecular systems. The dynamical evolution of the response of atoms and molecules to intense disturbances is accessible to experimental investigation with high fields and short pulses, and many new phenomena have been uncovered in consequence.

The standard treatment of the effects of electromagnetic fields on atoms and molecules makes use of the weakness of their interaction with the radiation field; it also assumes time scales that are long compared with the characteristic periods of the unperturbed systems. First-order perturbation theory suffices to describe the phenomena. Transitions between energy levels occur by the emission or absorption of a single photon with an energy equal to the difference between the unperturbed energy levels of the initial and final states. Transition probabilities for the energy levels can be defined independently of the photon intensity. The selection rules are simple. And the polarization pattern is readily predictable.

As the intensity of the radiation field increases, however, phenomena occur that cannot be reproduced by a first-order theory: multiphoton transitions, complex selection rules, complex polarization patterns and shifts in the energy levels. Multiphoton transitions take place via intermediate resonance states; the relaxation of the resonance states may occur on time scales that compete with those for emission and absorption. In multimode lasers, harmonic generation creates photons with frequencies equal to the sum of the frequencies of individual photons. Multiphoton transitions into the continuum are possible at high field strengths, and the spectrum of the ejected photoelectrons depends on the laser pulse lengths.

Not all the observed effects can, as yet, be explained in quantitative detail, but considerable progress has been made in developing and testing perturbative and nonperturbative methods that have predictive power. In perturbative methods, diagrammatic techniques have been worked out for handling the detailed enumeration of the transition matrix elements, and procedures have been

constructed for accelerating the convergence of the perturbation series. For a broad class of problems, the perturbative methods fail and must be replaced by procedures that embody variational constraints. Several such procedures have been introduced based on the Floquet theory of differential equations.

Farhad Faisal has been deeply involved in the theoretical developments important to this subject. His book *Theory of Multiphoton Processes* is a clear, comprehensive account of the available methods for the quantitative description of the effects of intense laser fields on atoms. It is self-contained and provides an excellent introduction to the formal theories and the methods of their evaluation in specific cases. It will help novice theorists considerably. However, it makes only occasional contact with experiment and it does not often stray into those interesting areas where interpretations remain uncertain.

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Computer Simulation of Liquids

M. P. Allen and D. J. Tildesley
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Liquids are ubiquitous in everyday life. They are so common that often we take their unusual and varied properties for granted. The advent of powerful computers has made the numerical simulation of the behavior of liquids a viable technique for attacking a broad range of problems. These simulations provide a direct link between microscopic features such as the masses, geometries and interactions of atoms and macroscopic properties accessible to experiment such as the equation of state and transport coefficients. In contrast to laboratory experiments with liquids, there are no difficulties with contaminant effects, optical distortion or microscopic visualization. Unlike analytic methods, no assumptions about correlations in intermolecular distribution functions are required. Often these simulations provide independent information at the microscopic level that is not obtainable by experiment.

M. P. Allen and D. J. Tildesley have written a useful primer on how to use the computer to carry out Monte Carlo and molecular dynamics simulations of liquids. The most important contribution, particularly for the computer