Purpose and Content of the Course

This is a one-semester graduate course on the non-relativistic quantum theory of radiation. The instructor has developed and been teaching this course for the past twenty-eight years to engineering students preparing to enter doctoral research in the area of Radiation Science and Technology (RST) in the Nuclear Engineering Department at the Massachusetts Institute of Technology. The course, entitled "Interaction of Radiation with Matter" has been required for all students in RST in the Ph.D. qualifying examination. The aim has been to teach graduate students in engineering the basic principles underlying the interaction of electromagnetic and neutron radiations with atomic and molecular systems. The emphasis is on applications to modern-day materials research.

The primary audience for this course is first and second-year graduate students having a BS degree in science or engineering from a standard four-year university. It is assumed that the student has taken a year of general physics and chemistry, advanced calculus, differential equations, and linear algebra. In addition, it is extremely helpful if the student has experienced a one-semester course in modern physics in which basic quantum theory and introductory nuclear physics are taught. The basic lecture notes developed by SHC were designed for a one-semester course, however, the accompanied text book, entitled "Interaction of Neutrons and Photons with Matter-An Introduction" (World Scientific Pub., 1997) reflects a highly expanded presentation of the original material, in terms of both content and exposition, developed by the co-author Michael Kotlarchyk. Depending on the choice of topics covered by the instructor, this book could serve as the text for either a one-semester or a two-semester course. In either case, most of the first nine chapters should be covered. A two-semester course allows for the study of extended applications appearing in Chapters 10--13.

The aim of the first four chapters of this book is to rapidly elevate the reader's knowledge of fundamental physics to a more advanced level. The student is introduced to the Lagrangian and Hamiltonian formulations of classical mechanics, important elements of classical electrodynamics (including Maxwell's equations, electromagnetic potentials, and the wave equation), and standard nonrelativistic quantum mechanics based on the Dirac formalism. In addition, the treatment of electrodynamics (Chapter 4) includes substantial material on the theory of classical light scattering.

Chapters 5--7 focus on the quantization of radiation and lattice-displacement fields, time-dependent perturbation theory and transition probabilities, as well as the equilibrium and time-evolution properties of the density operator in statistical mechanics. Chapter 6 also contains a section on the formulation of the double-differential cross-section for the scattering of photons and thermal neutrons (the latter based on the Fermi pseudo-potential). At this point, the student should be prepared to understand basic aspects of the quantum theory of radiation. Chapters 8 and 9 present the topics of photon emission, absorption, and scattering.

The next three chapters illustrate how the theories learned earlier on can be used to understand a number of useful experimental techniques. Examples are chosen from the areas of nuclear magnetic resonance, photon correlation spectroscopy, and thermal neutron scattering. These choices reflect both the expertise of the authors and the interests of students in the M.I.T. Nuclear Engineering Department.

The final chapter presents, in a concise way, the modern view of the general relationship between theory and experiment in terms of equilibrium correlation functions.