Preface to the 2nd Edition

In the second edition, we have made a number of corrections of minor typographical errors in the first edition. More problems, and several new chapters and sections have been added, in particular:

1 Several sections on Lie groups and algebras with symplectification and integration algorithms to Chapter 3.

2 Expanded discussions of linear coupling, eigenvalues, and stability in chapters 3, 6, and 10.

3 A new chapter on spin dynamics with a detailed discussion of spin, spin precession, spinors, depolarizing resonances, effect of crossing a spin resonance, Siberian snakes, and the invariant spin field.

4 A new chapter which discusses how beam position measurements are made, and the power spectra of bunched beams.

5 An expanded appendix calculating luminosity of colliding beams.

6 A new appendix on the leap-frog integration technique.

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Preface to the 1st Edition

Our purpose in writing this book has been to provide a concise and coherent introduction to the physics of particle accelerators, with attention being paid to the design of an accelerator for use as an experimental tool. The book has grown from the lecture notes for courses given at the Texas Accelerator Center, Texas A&M University, and the Università di Genova. The book is intended for study at the graduate level in physics, and may be used as a text for either a one semester course or self-study. It is hoped that the reader will also find this work to be a useful reference. We have assumed that the student has an undergraduate knowledge of electrodynamics, special relativity, and a knowledge of classical mechanics including basic Hamiltonian formalism.

This subject brings together several areas of classical physics (particularly classical mechanics, special relativity, electrodynamics, and statistical mechanics) by applying them to a concrete example which is nearly linear. As such it provides an excellent pedagogical framework to gain greater insight into these basic fields.

The book is organized into twelve chapters, the first six of which deal mainly with transverse motion of single particles:

1 An introduction describing various types of accelerators, a discussion of the end parameters needed to make the accelerator a useful tool, and a short review of relativity.

2 Weak focusing with a simple treatment of particle motion.

3 A more general study of particle trajectories using Hamiltonian formalism, symplectic transformations, and Liouville's theorem.

4 An introduction to field expansions of various beam transport magnets.

5 Strong focusing with the concepts of emittance, dispersion, and the Twiss parameters.

6 Applications demonstrating calculation techniques, optimization of compound optical elements, coupled motion, and chromatic effects.

The next three chapters introduce longitudinal motion of single particles:

7 Synchrotron oscillations.

8 Effects of synchrotron radiation on beam trajectories.

9 Linear accelerators.

Chapter 10 is an introduction to resonances:

10 A study of resonance behavior including coupled motion and nonlinear effects.

The last two chapters examine some collective effects of beams:

11 Space charge effects with self-beam and beam-beam interactions.

12 Two methods for circumventing Liouville's theorem: electron and stochastic cooling.

Problems of varying difficulty are included at the ends of each chapter to give the reader an opportunity to obtain a deeper understanding of the topics. Several appendices are included either to give background material or to elaborate a specific point. The first appendix is included to minimize confusion by reconciling incompatible definitions and symbols of different authors (note especially emittance.)

The authors are very grateful to the students who have given feedback and enabled us to improve the text and problems. We would especially like to thank Professor Sho Ohnuma for his comments.