

CONTENTS

PREFACE	v
Chapter 1 SYMMETRIES AND CONSERVATION LAWS	2
1-1 Nuclear Constitution	2
Illustrative Examples to Section 1-1	6
1-2 Nuclear Symmetry Properties Associated with Space-Time Invariance	7
1-2a Continuous Transformations	7
1-2b Space Reflection	13
1-2c Time Reversal	16
Illustrative Examples to Section 1-2	21
1-3 Isobaric Invariance	31
1-3a Isospin Symmetry	31
1-3b Extension of Isobaric Symmetry	38
Illustrative Examples to Section 1-3	42
1-4 Invariance Conditions for Nuclear Forces	65
1-4a Velocity-Independent Forces	66
1-4b Velocity-Dependent Forces	68
Appendix 1A: Rotational Invariance	70
1A-1 Angular Momentum Matrices	70
1A-2 Coupling of Angular Momenta	71
1A-3 Recoupling Coefficients	72
1A-4 Rotation Matrices. \mathcal{D} Functions	75
1A-5 Spherical Tensors and Reduced Matrix Elements	80
1A-6 Transformation to Intrinsic Coordinate System	87
1A-7 Transformation of Fields	90

1A-8	Field Couplings and Expansion in Multipole Moments	91
1A-9	Tensors in Isospace	95
Appendix 1B: Time Reversal		96
1B-1	Single-Particle States	96
1B-2	Many-Particle States (Bound Systems)	98
1B-3	Collision Processes	100
1B-4	Decay Processes	102
Appendix 1C: Permutation Symmetry		104
1C-1	Symmetry Quantum Numbers (Partitions)	105
1C-2	Symmetry Classification of Wave Functions in Occupation Number Space	116
1C-3	Unitary Symmetry	121
	Illustrative Examples to Appendix 1C	127
Chapter 2	INDEPENDENT-PARTICLE MOTION	137
2-1	Bulk Properties of Nuclei	138
2-1a	Nuclear Size	138
2-1b	Mean Free Path of Nucleons	139
2-1c	Momentum Distribution (Fermi Gas Approximation)	139
2-1d	Nuclear Binding Energies	141
2-1e	Pairing Energy	143
2-1f	Isospin Quantum Number	144
2-1g	Nuclear Potential	146
2-1h	Antisymmetrized Fermi Gas Wave Functions	149
2-1i	Statistical Features of Excitation Spectrum	152
	Illustrative Examples to Section 2-1	158
2-2	Evidence for Nuclear Shell Structure	189
2-2a	Binding Energies	189
2-2b	Excitation Energies of Even-Even Nuclei	190
2-2c	Level Densities	190
	Illustrative Examples to Section 2-2	191
2-3	Nuclear Species and Abundances	198
2-3a	Nuclear Stability	198
2-3b	Relative Abundances and Nucleogenesis	199
	Illustrative Examples to Section 2-3	203

2-4	Average Nuclear Potential	208
2-4a	Sequence of Single-Particle Levels. Spin-Orbit Coupling	208
2-4b	Single-Particle Strength Function	211
2-4c	Optical Potential	213
	Illustrative Examples to Section 2-4	220
2-5	Nucleonic Interactions and Nuclear Potential	240
2-5a	Main Features of Nucleonic Interaction	240
2-5b	Relation of Nuclear Potential to Nucleonic Interactions	251
2-5c	Theory of Nuclear Matter	262
	Illustrative Examples to Section 2-5	263
Appendix 2A: Antisymmetrized Product States. Creation and Annihilation Operators		272
2A-1	Antisymmetric Wave Functions	272
2A-2	Properties of Creation Operators for Fermions	273
2A-3	One-Particle Operators	275
2A-4	Two-Particle Operators	276
2A-5	Particle Transfer Operators	277
2A-6	x Representation	277
2A-7	Density Matrices	278
2A-8	Creation Operators for Bosons	279
Appendix 2B: Statistical Calculation of Nuclear Level Densities		281
2B-1	Level Density Function and its Laplace Transform	281
2B-2	Inversion of Laplace Transform	283
2B-3	Average Occupation Numbers for One-Particle States	285
2B-4	Description of Spectrum in Terms of Quasiparticle Excitations	286
2B-5	Thermodynamic Interpretation of Level Density Calculation	288
2B-6	Calculation of Level Densities Specified by Additional Quantum Numbers	289
Appendix 2C: Fluctuations in Terms of Random Matrices		294
2C-1	Random Distribution of Elements of Two-Dimensional Matrix	294
2C-2	Distribution of Eigenvalues and Eigenvectors	296
2C-3	Matrices of Large Dimensions	298

Appendix 2D: Model for Strength Function Phenomena	302
2D-1 Choice of Representation	302
2D-2 Diagonalization	303
2D-3 Strength Function for Constant Matrix Elements	303
2D-4 Time-Dependent Description of Coupling Process	304
2D-5 Second Moment of Strength Function	305
2D-6 Intermediate Coupling Stages	305
2D-7 Evaluation of Strength Function for Nonconstant Matrix Elements	306
 <i>Chapter 3</i> SINGLE-PARTICLE CONFIGURATIONS	 309
3-1 Quantum Numbers and Wave Functions. Particle-Hole Symmetry	310
3-1a One-Particle States	310
3-1b Hole States. Particle-Hole Conjugation	312
3-1c Isospin for Particle and Hole States	313
Illustrative Examples to Section 3-1	315
3-2 Energy Spectra	317
Illustrative Examples to Section 3-2	318
3-3 Matrix Elements of Electromagnetic Moments	332
3-3a Quadrupole Moments and $E2$ -Transition Probabilities	332
3-3b Magnetic Moments	336
3-3c Other Electromagnetic Moments	340
Illustrative Examples to Section 3-3	341
3-4 Beta-Decay Matrix Elements	345
3-4a Allowed Transitions	345
3-4b Forbidden Transitions	348
Illustrative Examples to Section 3-4	349
3-5 Reaction Processes. Parentage Coefficients	354
3-5a One-Particle Transfer Reactions	354
3-5b Resonance Reactions	355
Illustrative Examples to Section 3-5	356
 Appendix 3A: One-Particle Wave Functions and Matrix Elements	 360
3A-1 Coupling of Spin and Orbit	360
3A-2 Evaluation of Matrix Elements for One-Particle Operators	362

Appendix 3B: Particle-Hole Conjugation	367
3B-1 Description of Fermion Systems in Terms of Particles and Holes	367
3B-2 Matrix Elements of One-Particle Operators	370
3B-3 Matrix Elements of Two-Particle Operators	373
Appendix 3C: Matrix Elements for Electromagnetic Interactions	379
3C-1 Coupling of Field and Current	379
3C-2 Radiative Processes	380
3C-3 Interactions with Charged Particles	383
3C-4 Charge and Current Density for Free Nucleons	384
3C-5 Single-Particle Matrix Elements	387
3C-6 Interaction Effects in the Current	389
Appendix 3D: Beta Interaction	395
3D-1 Weak Interaction Processes and Weak Current	395
3D-2 Symmetry Properties of β Current	398
3D-3 Nonrelativistic Form of β Current	402
3D-4 Multipole Moments	406
3D-5 ft Values	410
Illustrative Examples to Appendix 3D	414
Appendix 3E: Nucleon Transfer Reactions	420
3E-1 Single-Nucleon Transfer	421
3E-2 Two-Particle Transfer	425
Appendix 3F: Resonance Reactions	428
3F-1 General Features of Resonance Scattering	428
3F-2 Resonance Parameters Calculated for Single-Particle Motion	437
BIBLIOGRAPHY	449
INDEX	465