## **Contents**

| 1 | Way  | ve Packets   | 1   |
|---|------|--|-----|
|   | 1.1  | The stationary-state wavefunction  | 2   |
|   | 1.2  | Introduction of packet states  | 2 3 |
|   | 1.3  |  | 6   |
|   | 1.4  | Cross sections   | 10  |
|   | 1.5  | Transition amplitude   | 10  |
|   | 1.6  | Recapitulation   | 11  |
|   | 1.7  | Time-reversed motion   | 12  |
|   | 1.8  | Three-body final states  | 13  |
|   |      | References   | 17  |
| 2 | Dire | ect Reactions  | 19  |
|   | 2.1  | Time delay: energy averaging   | 20  |
|   | 2.2  | Alternative definition of DI   | 23  |
|   | 2.3  | Consequences of CN models  | 27  |
|   | 2.4  | Conditions for direct reactions  | 30  |
|   | 2.5  | Boundary-matching theories   | 38  |
|   | 2.6  | Angular distribution, angular correlations   | 39  |
|   | 2.7  | Wave-packet study of three-body breakup  | 40  |
|   |      | References   | 42  |
| 3 | Som  | ne Useful Formulas   | 45  |
|   | 3.1  | Projection of $\Psi^{(+)}$ on channel $\beta$  | 45  |
|   | 3.2  | Spherical distorted waves  | 48  |
|   | 3.3  | Generalized distorting potential   | 53  |
|   | 3.4  | Some integral equations  | 54  |
|   | 3.5  | Antisymmetrization   | 58  |
|   |      | References   | 62  |
| 4 | Basi | ic DI Theories   | 63  |
|   | 4.1  | Introduction of simple models  | 63  |
|   |      | Elimination of the compound nucleus  | 65  |
|   | 4.3  | The state of the s | 73  |
|   | 44   | The DI transition amplitude  | 77  |

viii CONTENTS

|   | 4.5  | Distorted-waves approximation                                  | 78  |
|---|------|--|-----|
|   | 4.6  | The method of coupled channels                                 | 84  |
|   | 4.7  | Three-body models  | 90  |
|   | 4.8  | Antisymmetrization   | 91  |
|   | 4.9  | Influence of antisymmetrization on calculation of relative     |     |
|   |      | wave functions   | 95  |
|   |      | References   | 97  |
|   |      |  |     |
| 5 | Appl | ications of the DW Method                                      | 99  |
|   | 5.1  | Zero-range approximation                                       | 99  |
|   | 5.2  | The optical potentials   | 103 |
|   | 5.3  | Inelastic scattering of strongly-absorbed projectiles          | 115 |
|   | 5.4  | Coulomb excitation   | 129 |
|   | 5.5  | Inelastic scattering of nucleons                               | 134 |
|   | 5.6  | Distorted-waves impulse approximation                          | 143 |
|   | 5.7  | Charge-exchange scattering                                     | 148 |
|   | 5.8  | Deuteron stripping   | 157 |
|   | 5.9  | Coulomb stripping  | 181 |
|   | 5.10 | Other single-nucleon transfer                                  | 185 |
|   |      | Multiple-nucleon transfer                                      | 192 |
|   | 5.12 | Knockon and heavy-particle stripping                           | 208 |
|   |      | Finite range   | 211 |
|   | 5.14 | Heavy-ion transfer reactions                                   | 218 |
|   |      | References   | 224 |
| _ | 1.   | About County Channels  | 230 |
| 6 |      | e About Coupled Channels                                       | 230 |
|   |      | Inelastic scattering Inclusion of closed channels              | 241 |
|   |      |  | 242 |
|   |      | Adiabatic theory   | 244 |
|   |      | Coupled isobaric channels  DW applications of coupled channels | 248 |
|   |      | Rearrangement and exchange                                     | 253 |
|   | 0.0  | References   | 256 |
|   |      | References   | 250 |
| 7 | Wav  | efunction Models, High Energy                                  | 258 |
|   | 7.1  | Properties of optical-model wavefunctions                      | 258 |
|   | 7.2  | Applications of <b>r</b> -space models: Diffraction            | 265 |
|   |      | WKB: High-energy method  | 273 |
|   | 7.4  | Applications of L-space models: Austern-Blair theory           | 278 |
|   |      | References   | 286 |

| CONTENTS    | ix |
|-------------|----|
| -9.1.2-1.12 |    |

| 8   | Spect | roscopic Applications of Stripping    | 288 |
|-----|-------|---------------------------------------|-----|
|     | 8.1   | $\mathscr S$ factors for simple cases | 289 |
|     | 8.2   | Sum rules                             | 294 |
|     | 8.3   | Collective nuclei                     | 300 |
|     | 8.4   | Radial form factors                   | 304 |
|     |       | References                            | 310 |
| 9   | Polar | izations and Angular Correlations     | 312 |
|     | 9.1   | Description of a polarized system     | 314 |
|     | 9.2   | Polarization in collision experiments | 319 |
|     | 9.3   | Polarization in the DW theory         | 324 |
|     | 9.4   | Angular correlations                  | 332 |
|     |       | References                            | 336 |
| 10  | DW    | Exchange and Recoil Effects           | 339 |
|     | 10.1  |                                       | 341 |
|     | 10.2  | Recoil effects                        | 347 |
|     | 10.3  | Knockon                               | 349 |
|     | 10.4  | Heavy ions                            | 354 |
|     |       | References                            | 357 |
| 11  | Unif  | fied Theories, Dispersion Theories    | 358 |
|     | 11.1  | Unified theories                      | 358 |
|     | 11.2  | Dispersion theories                   | 370 |
|     |       | References                            | 375 |
| Ge  | neral | References                            | 377 |
| Ind | lex   |                                       | 379 |