

# Contents

|          |                                        |    |
|----------|----------------------------------------|----|
| <b>1</b> | <b>Introduction</b>                    | 1  |
| 1.1      | Properties of Elementary Charges       | 1  |
| 1.2      | Charge Density in Molecules            | 4  |
| 1.2.1    | Self Energy of Hydrogen Atom           | 4  |
| 1.2.2    | Charge Density in Molecules            | 6  |
| 1.2.3    | Charge Density in Hydrogen-Like Atom   | 8  |
| 1.2.4    | Electric Dipole of Molecules           | 9  |
| 1.2.5    | Van der Waals Potential                | 14 |
| 1.3      | Structure of Molecules                 | 19 |
| 1.3.1    | Adiabatic Approximation                | 22 |
| 1.3.2    | Hydrogen Atom in Harmonic Oscillator   | 28 |
| <b>2</b> | <b>Relativistic Wave Equations</b>     | 33 |
| 2.1      | Unifying Equation                      | 33 |
| 2.2      | Homogeneous Equation                   | 35 |
| 2.3      | Inhomogeneous Equation                 | 41 |
| 2.3.1    | General Features                       | 41 |
| 2.3.2    | Electromagnetic Field                  | 43 |
| 2.3.3    | Klein-Gordon Equation                  | 52 |
| 2.3.4    | Dirac Equation                         | 54 |
| <b>3</b> | <b>Electrodynamics</b>                 | 67 |
| 3.1      | Basic Principles                       | 67 |
| 3.2      | Vector and Scalar Potentials           | 69 |
| 3.3      | Electromagnetic Waves                  | 74 |
| 3.3.1    | General Features                       | 74 |
| 3.3.2    | Plane Waves                            | 77 |
| 3.3.3    | Short Pulses                           | 80 |
| 3.3.4    | Finite Width Waves                     | 85 |
| 3.3.5    | Beam Focusing (Paraxial Approximation) | 91 |

|          |                                                    |     |
|----------|----------------------------------------------------|-----|
| <b>4</b> | <b>Charge in Electromagnetic Wave</b>              | 101 |
| 4.1      | Basic Effects                                      | 101 |
| 4.1.1    | Classical Dynamics                                 | 101 |
| 4.1.2    | Quantum Dynamics                                   | 108 |
| 4.2      | Very Short Electromagnetic Pulse                   | 119 |
| 4.2.1    | Impact on Hydrogen Atom                            | 119 |
| 4.2.2    | Impact On Atom                                     | 125 |
| 4.3      | Field Reaction                                     | 127 |
| <b>5</b> | <b>Confinement of Charge</b>                       | 133 |
| 5.1      | General Remarks                                    | 134 |
| 5.1.1    | Uniform Velocity                                   | 136 |
| 5.1.2    | Decay of Two Particle System                       | 141 |
| 5.2      | Confinement by Magnetic Field                      | 147 |
| 5.2.1    | Time Dependent Magnetic Field                      | 150 |
| 5.3      | Confinement with Electromagnetic Wave              | 155 |
| 5.3.1    | Classical Dynamics                                 | 155 |
| 5.3.2    | Charge in Standing Wave                            | 157 |
| 5.3.3    | Generalized Standing Wave                          | 159 |
| 5.3.4    | Gaussian Polarization                              | 162 |
| 5.3.5    | Quantum Dynamics                                   | 166 |
| 5.4      | Extreme Confinement                                | 177 |
| 5.4.1    | One Particle                                       | 177 |
| 5.4.2    | Two Particles                                      | 181 |
| 5.4.3    | Charge Density                                     | 198 |
| <b>6</b> | <b>Atom in Electromagnetic Field</b>               | 217 |
| 6.1      | General Remarks                                    | 217 |
| 6.2      | Atom in Electromagnetic Wave                       | 219 |
| 6.2.1    | Basic Equation                                     | 219 |
| 6.2.2    | First Order Interaction                            | 223 |
| 6.2.3    | Second Order Interaction                           | 236 |
| <b>7</b> | <b>Radiation by Charge</b>                         | 239 |
| 7.1      | Radiation Zone                                     | 239 |
| 7.2      | Radiation by Created Charge                        | 246 |
| 7.3      | Radiation by a Bound Charge                        | 254 |
| 7.3.1    | Hydrogen Atom                                      | 254 |
| 7.3.2    | Radiation by Rotating Molecule                     | 260 |
| 7.3.3    | Radiation by Vibrating Molecule                    | 269 |
| 7.3.4    | Spectral Line Shifts                               | 277 |
|          | <b>Appendix A: Units</b>                           | 287 |
|          | <b>Appendix B: Nonrelativistic Green Functions</b> | 291 |

**Appendix C: Useful Relationships . . . . . 301**

**Appendix D: System of N Particles . . . . . 307**

**References . . . . . 329**

**Index . . . . . 331**