
Contents

Part I A Treatise on Radiation Theory

| | | |
|----------|--|-----------|
| 1 | Maxwell's Equations | 3 |
| 1.1 | Microscopic Electrodynamics | 3 |
| 1.1.1 | Microscopic Charges | 4 |
| 1.1.2 | The Field Equations | 6 |
| 1.2 | Variational Principle | 11 |
| 1.3 | Conservation Theorems | 14 |
| 1.4 | Delta Function | 17 |
| 1.5 | Radiation Fields | 18 |
| 1.5.1 | Multipole Radiation | 23 |
| 1.5.2 | Work Done by Charges | 31 |
| 1.6 | Macroscopic Fields | 34 |
| 1.7 | Problems for Chap. 1 | 36 |
| 2 | Spherical Harmonics | 45 |
| 2.1 | Connection to Bessel Functions | 45 |
| 2.2 | Multipole Harmonics | 50 |
| 2.3 | Spherical Harmonics | 53 |
| 2.4 | Multipole Interactions | 59 |
| 2.5 | Problems for Chap. 2 | 63 |
| 3 | Relativistic Transformations | 65 |
| 3.1 | Four-Dimensional Notation | 65 |
| 3.2 | Field Transformations | 70 |
| 3.3 | Problems for Chap. 3 | 72 |
| 4 | Variational Principles for Harmonic Time Dependence | 81 |
| 4.1 | Variational Principles | 82 |
| 4.2 | Boundary Conditions | 86 |
| 4.3 | Babinet's Principle | 91 |

| | | | | | |
|-----------|---|-----|-----------|--|-----|
| 4.4 | Reciprocity Theorems | 93 | 11 | Examples of Variational Calculations for Circular Guide | 215 |
| 4.5 | Problems for Chap. 4 | 94 | 11.1 | E Modes | 215 |
| 5 | Transmission Lines | 97 | 11.1.1 | Bounds on Second Eigenvalue | 219 |
| 5.1 | Dissipationless Line | 97 | 11.2 | H Modes | 225 |
| 5.2 | Resistive Losses | 100 | 11.3 | Problems for Chap. 11 | 227 |
| 5.3 | Example: Coaxial Line | 101 | 12 | Steady Currents and Dissipation | 229 |
| 5.4 | Cutoff Frequencies | 102 | 12.1 | Variational Principles for Current | 229 |
| 5.5 | Problems for Chap. 5 | 103 | 12.2 | Green's Functions | 233 |
| 6 | Waveguides and Equivalent Transmission Lines | 105 | 12.3 | Problems for Chap. 12 | 236 |
| 6.1 | Transmission Line Formulation | 105 | 13 | The Impedance Concept in Waveguides | 237 |
| 6.2 | Hertz Vectors | 114 | 13.1 | Waveguides and Equivalent Transmission Lines | 237 |
| 6.3 | Orthonormality Relations | 115 | 13.2 | Geometrical Discontinuities and Equivalent Circuits | 238 |
| 6.4 | Energy Density and Flux | 117 | 13.2.1 | <i>S</i> -Matrix | 238 |
| 6.5 | Impedance Definitions | 120 | 13.3 | Normal Modes | 242 |
| 6.6 | Complex Poynting and Energy Theorems | 123 | 13.3.1 | Shift of Reference Point | 244 |
| 6.7 | Problems for Chap. 6 | 129 | 13.3.2 | Lumped Network Description | 246 |
| 7 | Rectangular and Triangular Waveguides | 135 | 13.3.3 | Energy | 250 |
| 7.1 | Rectangular Waveguide | 135 | 13.4 | Variational Principle | 251 |
| 7.2 | Isosceles Right Triangular Waveguide | 143 | 13.5 | Bifurcated Guide | 253 |
| 7.3 | Equilateral Triangular Waveguide | 145 | 13.6 | Imperfect Conducting Walls | 258 |
| 7.4 | Problems for Chap. 7 | 154 | 13.7 | Conclusion | 262 |
| 8 | Circular Cross Section | 155 | 13.8 | Problems for Chap. 13 | 262 |
| 8.1 | Cylinder Functions | 156 | 14 | Accelerators: Microtrons and Synchrotrons | 265 |
| 8.2 | Circular Guide | 160 | 14.1 | The Microtron | 265 |
| 8.3 | Circular Guide with Metallic Cylindrical Wedge | 165 | 14.1.1 | Cavity Resonators | 266 |
| 8.4 | Coaxial Guide | 167 | 14.1.2 | Elementary Theory | 269 |
| 8.5 | Coaxial Guide with Metallic Cylindrical Wedge | 169 | 14.1.3 | Vertical Defocusing | 270 |
| 8.6 | Elliptic and Parabolic Cylinder Coordinates | 171 | 14.1.4 | Radiation Losses | 271 |
| 8.7 | Problems for Chap. 8 | 176 | 14.1.5 | Phase Focusing | 272 |
| 9 | Reflection and Refraction | 181 | 14.2 | Excitation of a Cavity by Electrons | 273 |
| 9.1 | Problems for Chap. 9 | 184 | 14.3 | Microwave Synchrotron | 277 |
| 10 | Variational Methods | 187 | 14.3.1 | Accelerating Cavities | 277 |
| 10.1 | Variational Principles | 187 | 14.3.2 | Motion of Electron | 277 |
| 10.2 | Rayleigh's Principle | 190 | 14.3.3 | Betatron Regime: $\mathcal{E}_0 = 0, \Phi_0 = 2\pi R^2 H_0(t)$ | 279 |
| 10.3 | Proof of Completeness | 197 | 14.3.4 | Betatron Regime and Constant H_0 | 280 |
| 10.4 | Variation-Iteration Method | 202 | 14.4 | Modern Developments | 281 |
| 10.4.1 | Error Estimates | 208 | 14.5 | Problems for Chap. 14 | 281 |
| 10.5 | Problems for Chap. 10 | 212 | | | |

| | |
|--|-----|
| 15 Synchrotron Radiation | 283 |
| 15.1 Relativistic Larmor Formula | 283 |
| 15.2 Energy Loss by a Synchrotron | 285 |
| 15.3 Spectrum of Radiation Emitted by Synchrotron | 286 |
| 15.4 Angular Distribution of Radiated Power | 290 |
| 15.5 Historical Note | 294 |
| 15.6 Problems for Chap. 15 | 295 |
| 16 Diffraction | 297 |
| 16.1 Variational Principle for Scattering | 297 |
| 16.2 Scattering by a Strip | 300 |
| 16.2.1 Normal Incidence | 300 |
| 16.2.2 Grazing Incidence | 303 |
| 16.2.3 General Incident Angle | 306 |
| 16.3 Diffraction by a Slit | 309 |
| 16.3.1 Approximate Field | 314 |
| 16.3.2 Transform of Scattered Field | 314 |
| 16.3.3 Differential Cross Section | 315 |
| 16.3.4 First Approximation | 316 |
| 16.3.5 Exact Electric Field | 320 |
| 16.3.6 Approximate Surface Current | 322 |
| 16.4 Problems for Chap. 16 | 326 |
| 17 Quantum Limitations on Microwave Oscillators | 331 |
| 17.1 Introduction | 331 |
| 17.2 Coherent States | 331 |
| 17.3 Harmonic Oscillator | 336 |
| 17.4 Free Particle | 338 |
| 17.5 Electron Interacting with an Oscillator | 340 |
| 17.5.1 Extreme Quantum Limit | 345 |
| 17.5.2 Correlations | 347 |
| 17.6 Problems for Chap. 17 | 348 |
| Appendix Electromagnetic Units | 349 |

Part II Relevant Papers of Julian Schwinger

| | |
|--|-----|
| Section A Waveguides | 355 |
| On the Representation of the Electric and Magnetic Fields Produced by Currents and Discontinuities in Wave Guides I (with <i>N. Marcwitz</i>) | 357 |

| | |
|---|-----|
| Section B Synchrotrons and Synchrotron Radiation | 371 |
| Electron Orbits in the Synchrotron (<i>with D. Saxon</i>) | 373 |
| On Radiation by Electrons in a Betatron | 383 |
| On the Classical Radiation of Accelerated Electrons | 409 |
| The Quantum Correction in the Radiation by Energetic Accelerated Electrons | 423 |
| Classical Radiation of Accelerated Electrons II. A Quantum Viewpoint | 429 |
| Classical and Quantum Theory of Synergic Synchrotron-Čerenkov Radiation (<i>with W.-Y. Tsai and T. Erber</i>) | 435 |
| New Approach to Quantum Correction in Synchrotron Radiation (<i>with W.-Y. Tsai</i>) | 465 |
| Section C Diffraction | 487 |
| On the Radiation of Sound from an Unflanged Circular Pipe (<i>with H. Levine</i>) | 489 |
| On the Theory of Diffraction by an Aperture in an Infinite Plane Screen I (<i>with H. Levine</i>) | 513 |
| On the Theory of Diffraction by an Aperture in an Infinite Plane Screen II (<i>with H. Levine</i>) | 531 |
| On the Transmission Coefficient of a Circular Aperture (<i>with H. Levine</i>) | 541 |
| On the Theory of Electromagnetic Wave Diffraction by an Aperture in an Infinite Plane Conducting Screen (<i>with H. Levine</i>) | 543 |
| References | 581 |
| Index | 583 |