
Table of Contents

Preface	ix
Chapter 1. Waveguides	1
1.1. The different types of waveguides	1
1.2. Description of a guided wave	2
1.2.1. Propagation equation and field expressions	2
1.2.2. Classification of propagation modes	6
1.3. TE and TM modes in a hollow conducting waveguide	8
1.3.1. Rectangular waveguide	9
1.3.2. Attenuation coefficient in a lossy waveguide	24
1.3.3. Propagation between two parallel planes	29
1.3.4. Cylindrical waveguide	33
1.4. Dielectric waveguides	37
1.4.1. Propagation between two parallel dielectric planes	37
1.4.2. Step index optical fiber	44
1.4.3. Modes with azimuthal symmetry	45
1.4.4. Modes with azimuthal dependence	48
1.4.5. Propagation modes in weakly guiding fibers	54
1.5. Resonant cavities	59
1.5.1. Rectangular metallic resonant cavity	60
1.5.2. Cylindrical resonant cavity	65
Chapter 2. Transmission Lines	71
2.1. Parallel-plate transmission line	71
2.2. General formulation	73
2.3. Modeling of lossless transmission lines	78
2.4. Modeling of a transmission line with losses	79
2.5. Wave equations and sinusoidal solutions	82

2.6. Effects of losses in transmission lines	86
2.6.1. Low-loss limit	87
2.6.2. Distortionless lines	87
2.6.3. Solutions with arbitrary impedance at the line output	88
2.7. Resonance effect in a transmission line	94
2.8. Energy aspect in a transmission line	95
Chapter 3. Electromagnetic Radiation	99
3.1. Retarded potentials	99
3.1.1. Inhomogeneous wave equations	99
3.1.2. Solutions of the inhomogeneous wave equations	101
3.1.3. Solutions by Fourier analysis	102
3.2. Radiation from a localized oscillating source	106
3.2.1. Radiation from an electric dipole	113
3.2.2. Radiations from the magnetic moment and the electric quadrupole	119
3.2.3. Multipole radiation of order $l \geq 2$	127
3.2.4. Energy and angular momentum of multipolar fields	132
3.3. Radiation from an extended source	135
Chapter 4. Radiation from Point Charges	145
4.1. Liénard–Wiechert potentials	145
4.2. Fields of a moving point charge	147
4.3. Radiation from a charge in uniform motion	152
4.4. Radiation from a slowly moving charge	153
4.5. Radiation from a relativistic charge	154
4.5.1. Velocity and acceleration parallel	155
4.5.2. Acceleration perpendicular to velocity	158
4.5.3. General case	166
4.6. Frequency distribution of the radiated energy	170
4.7. Charge in instantaneous circular motion	177
4.8. Particle in circular motion	183
4.9. Thomson scattering of radiation	188
4.10. Cherenkov radiation	196
Chapter 5. Kirchhoff Diffraction	201
5.1. Initial value problem: Kirchhoff’s integral representation	201
5.1.1. Green’s function for the time-dependent wave equation	201
5.1.2. Cauchy problem	204
5.1.3. Poisson solution	205
5.1.4. Kirchhoff representation of the field	206

5.2. Kirchhoff integral for diffraction	207
5.3. Vector form of the Kirchhoff integral	212
5.4. Babinet's principle of complementary screens	217
5.5. Diffraction by a circular aperture	220
5.6. Scattering by a conducting sphere in the short-wavelength limit	231

Chapter 6. Theory of Special Relativity 241

6.1. Postulates of special relativity and Lorentz transformation	241
6.2. FitzGerald–Lorentz length contraction, time dilation and proper time	248
6.3. Law of addition of velocities	250
6.4. Four-dimensional Formalism	255
6.4.1. Brehme–Lorentz diagram	255
6.4.2. Transformations and Lorentz group	259
6.4.3. Contravariant coordinates	262
6.4.4. Covariant coordinates	263
6.4.5. Change of basis	264
6.4.6. Four-velocity, four-momentum and four-acceleration	266
6.4.7. Tensors	269
6.4.8. Differentiation, vector analysis and integration	272
6.5. Relativistic dynamics	274
6.5.1. Relativistic Lagrangian for a free particle	274
6.5.2. Four-momentum	275
6.5.3. Application to collisions	278
6.5.4. Minkowski four-force	280

Chapter 7. Covariant Formulation 285

7.1. A brief remark on field theory	285
7.1.1. Transition from a discrete system to a continuous one	285
7.1.2. Continuous system	286
7.1.3. Euler–Lagrange equations	287
7.1.4. Hamiltonian formalism	288
7.1.5. Gauge invariance	290
7.1.6. Infinitesimal symmetry	291
7.1.7. Energy–momentum tensor of a field	292
7.1.8. Angular momentum tensor	293
7.1.9. Electromagnetic interaction	293
7.2. Free particle in a field	294
7.2.1. Four-potential	294
7.2.2. Equation of relativistic dynamics	296
7.2.3. Electromagnetic field tensor	298
7.2.4. Lorentz force	300
7.2.5. Change of reference frames for the field	302

7.2.6. Invariants of the electromagnetic field	305
7.2.7. First group of Maxwell equations	306
7.3. Sources of the field: second group of Maxwell equations	307
7.3.1. Interaction between a field and a current	308
7.3.2. Free field action (field self-interaction)	309
7.3.3. Magnetization and polarization	311
7.4. Energy–momentum tensor	312
7.4.1. Conservation law	314
7.4.2. Time component: conservation of energy	315
7.4.3. Spatial components: conservation of momentum	316
7.5. Electromagnetic mass	318
7.6. Radiation reaction force from energy balance	321
7.7. Abraham–Lorentz model	325
7.8. Abraham–Lorentz equation of motion	332
7.9. Dirac radiation equation	334
7.10. And the story continues...	335
References	337
Index	343