



# Contents

## 1. SPACE- AND TIME-DEPENDENT LINEAR FIELDS 1

### 1.1 Formulation of Vector Field and Scalar Potential Problems, 1

#### 1.1a The Scalar Acoustic Field, 2

*General properties, 2*

*Scalar Green's function for unbounded space, 8*

#### 1.1b The Vector Electromagnetic Field, 9

*General properties, 9    Dyadic Green's functions in free space (invariant evaluation), 14    Classical method, 15    Operator method, 15    Field of an electric dipole current, 16    Dyadic Green's functions for free space (transversely invariant)—Hertz potentials, 17    Dyadic Green's functions for bounded cylindrical regions, 23*

#### 1.1c The Plasma Field (One-component Fluid Model), 26

*General properties, 26    Dyadic Green's functions for an unbounded, isotropic, electron plasma, 28    Reduced formulation of plasma field, 30*

#### 1.1d General Linear Field (Abstract Formulation), 31

*Acoustic field, 31    Electromagnetic field, 32    One-Component plasma field, 32*

### 1.2 Plane Wave Field Representations, 34

#### 1.2a The Acoustic Field, 36

*Steady-state power radiated by acoustic source, 40*

- 1.2b The Electromagnetic Field, 41
  - Steady-state power radiated by electric and magnetic currents in free space, 43*
- 1.2c The Plasma Field, 45
  - Steady-state power radiated by electric currents in unbounded plasma, 48*
- 1.2d General Linear Field, 49
- 1.3 Guided Wave (Oscillatory) Representations in Time, 50**
  - 1.3a General Linear Field, 52
  - 1.3b The Acoustic Field, 56
    - Oscillatory representation of acoustic Green's function, 57*
  - 1.3c The Electromagnetic Field, 58
    - Oscillatory representation of electromagnetic Green's function, 59*
  - 1.3d The Plasma Field, 60
    - Oscillatory representation of plasma Green's function, 62*
- 1.4 Guided Wave Representations in Space, 63**
  - 1.4a General Linear Field, 66
  - 1.4b The Acoustic Field, 68
  - 1.4c The Electromagnetic Field, 71
- 1.5 Reduced Electromagnetic Field Equations, 75**
  - 1.5a Energy Density, Power Flow, and Group Velocity for the Electromagnetic Field, 76
    - Energy density and power flow, 78*
    - Average energy transport (group velocity), 83*
  - 1.5b Boundary Conditions, Uniqueness, and Reciprocity Relations for the Electromagnetic Field, 86
    - Boundary conditions and uniqueness, 86*
    - Reciprocity relations, 90*

## 1.5c Alternative Representations, 93

**1.6 Ray-Optic Approximations of Integral Representations, 97**

## 1.6a Oscillatory Integral Representations, 98

*Homogeneous media, 98      Dispersion surfaces and space-time rays, 101      Weakly inhomogeneous media, 106*

## 1.6b Guided Wave Integral Representations, 108

*Homogeneous media (time-harmonic case), 108      z-stratified media (time-harmonic case), 111      z-stratified media (transient case), 114      Transients in non-dispersive configurations (closed-form inversion of time-harmonic result), 116*

## 1.6c Diffraction and Transition Phenomena, 117

*Transient and signal propagation in a magnetoplasma (interaction between wavepackets), 119      Field behavior near a wavefront prior to formation of a wavepacket, 122*

**1.7 Ray-Optic Approximations for Differential Equations, 123**

## 1.7a Rays and the Theory of Characteristics, 125

## 1.7b Scalar Time-Harmonic Fields, 128

*Ray trajectories, 130      Phase functions, 132      Amplitude variation, 132*

## 1.7c Vector Time-Harmonic Fields, 134

*Isotropic media, 134      Anisotropic media, 137*

## 1.7d The Geometrical Theory of Diffraction, 139

*Ray reflection and refraction laws, 142      Isotropic media, 143      Anisotropic media, 144      Warm isotropic plasma, 145      Diffracted rays, 146      Example: Diffraction by a conducting half-plane on the interface between two isotropic dielectrics, 149*

## 1.7e Transient Fields, 153

*Solution of the dispersion equation, 155      Solution of the transport equation, 155      Reflection and refraction of space-time rays, 156      Fields near the wavefront, 157*

|   |            |
|---|------------|
| <b>2. NETWORK FORMALISM FOR TIME-HARMONIC ELECTROMAGNETIC FIELDS IN UNIFORM AND SPHERICAL WAVEGUIDE REGIONS</b> | <b>183</b> |
| <b>2.1 Introduction,</b>  | <b>183</b> |
| <b>2.2 Derivation of Transmission-Line Equations in Uniform Regions,</b>  | <b>185</b> |
| 2.2a The Transverse Field Equations,  | 185        |
| 2.2b Modal Representations of the Fields and their Sources,   | 187        |
| <i>E (TM) modes,</i>  | <i>190</i> |
| <i>H (TE) modes,</i>  | <i>190</i> |
| <b>2.3 Scalarization and Modal Representation of Dyadic Green's Functions in Uniform Regions,</b>               | <b>190</b> |
| 2.3a Mode Functions,  | 191        |
| 2.3b Fields in Source-Free, Homogeneous Regions,  | 192        |
| 2.3c Green's Functions for Transmission-Line Equations,   | 193        |
| 2.3d Modal Representations of the Dyadic Green's Functions in a Piecewise Homogeneous Medium,                   | 195        |
| 2.3e Modal Representations of the Dyadic Green's Functions in an Inhomogeneous Medium,                          | 200        |
| <b>2.4 Solution of Uniform Transmission-Line Equations (Network Analysis),</b>                                  | <b>202</b> |
| 2.4a Source-free Case,  | 202        |
| 2.4b Point Source on an Infinite Transmission line,   | 205        |
| 2.4c Excitation of General Transmission-Line Network by a Point Source,   | 207        |
| 2.4d Green's Functions for Transmission-Line Equations,   | 210        |
| 2.4e Resonance Properties of Terminated Transmission Lines,   | 215        |
| <b>2.5 Derivation of Transmission-Line Equations in Spherical Regions,</b>                                      | <b>218</b> |
| 2.5a The Transverse Field Equations,  | 218        |
| 2.5b Modal Representation of the Fields and Their Sources,  | 219        |

## 2.6 Scalarization and Modal Representation of Dyadic Green's Functions in Spherical Regions, 222

2.6a Mode Functions, 222

2.6b Fields in Source-Free, Homogeneous Regions, 222

2.6c Modal Representations of the Dyadic Green's Functions, 224

## 2.7 Solution of Spherical Transmission-Line Equations (Network Analysis), 225

2.7a Source-Free and Source-Excited Transmission Lines, 225

2.7b Special Terminations, 229

*Bilaterally matched region, 229*

*Homogeneous region,  $0 < r < \infty$ , 230*

*Semiinfinite homogeneous region,  $0 < a \leq r < \infty$ , 230*

*Composite region,  $0 < r < \infty$ , 231*

## 3. MODE FUNCTIONS IN CLOSED AND OPEN WAVEGUIDES 239

### 3.1 Introduction, 239

### 3.2 Classical Evaluation of Mode Functions, 241

3.2a General One-Dimensional Eigenvalue Problem, 241

3.2b Homogeneously Filled Rectangular Cross-Sections, 243

*Finite rectangular region, 243      Semiinfinite rectangular region, 246      Quarter-space region, 248*

*Half-space region, 249      Free-space region, 251*

*Parallel-plate region, 252      Transmission-line interpretation of one-dimensional eigenvalue problem, 253*

3.2c Homogeneously Filled Cylindrical Cross-Sections, 254

*Finite angular sector, 257*

*Open angular sector, 259*

*Circular waveguide, 263*

*Free space, 264*

3.2d Inhomogeneously Filled Cross Sections, 265

*Transverse field equations and modal representations, 265*

*Evaluation of vector-mode functions by transverse transmission*

*analysis*, 268      *Homogeneous cross-section*, 269      *Inhomogeneous cross-section*, 271

### 3.3 Characteristic Green's Function (Resolvent) Procedure and Alternative Representations, 273

3.3a Relation Between Characteristic Green's Function and Eigenvalue Problems, 274

3.3b Construction of the Characteristic Green's Function, 278

3.3c Alternative Representations, 284

### 3.4 One-Dimensional Characteristic Green's Function and Eigenfunction Solutions, 289

3.4a Rectangular Cross Sections, 289

*Bounded  $x$  domains*, 289

*H modes (along  $x$ )*, 289

*E modes (along  $x$ )*, 294

*Characteristic Green's function*, 294

*Delta function representation*, 295

*Semi-infinite  $x$ -domain*, 296

*Infinite  $x$  domain*, 303

3.4b Angular Transmission Lines, 306

*Cylindrical regions*, 307

*Spherical regions*, 314

$0 \leq \theta \leq \pi$ , 319

$0 < \theta < \theta_0 < \pi$ , 320

$0 < \theta_1 \leq \theta \leq \theta_2 < \pi$ , 321

3.4c Radial Transmission Lines, 323

### 3.5 Approximate Methods for Solving the Non-Uniform Transmission-Line Equations, 328

3.5a Integral Equation Formulation, 329

3.5b The Comparison Equation, 336

3.5c Various comparison functions, 337

$\alpha_0(x)$  has no zeros or poles (WKB solution), 337       $\alpha_0(x)$  has a simple zero, 338       $\alpha_0(x)$  has two neighboring simple zeros, 341

$\alpha(x, \Omega)$  has a simple pole, 343

$\alpha(x, \Omega)$  has neighboring simple pole and simple zero, 344

|            |   |            |
|------------|---|------------|
| 3.5d       | Error Bounds on the Approximate Solutions, 345  |            |
| 3.5e       | Corrections to the WKB Approximation, 347   |            |
| <b>3.6</b> | <b>Application to Various Inhomogeneity Profiles, 350</b>   |            |
| 3.6a       | Reflection from a Continuous Transition, 350  |            |
| 3.6b       | The Epstein Solution for a Continuous Transition, 353   |            |
| 3.6c       | Dielectric Constant Profile with Simple Zero, 358   |            |
| <b>4.</b>  | <b>ASYMPTOTIC EVALUATION OF INTEGRALS</b>   | <b>370</b> |
| <b>4.1</b> | <b>General Considerations, 370</b>  |            |
| 4.1a       | Transformation to a Canonical Form, 370   |            |
|            | <i>Infinite integrals, 370      Integrals with finite endpoints, 375</i>                            |            |
| 4.1b       | Saddle Points and Paths of Constant Level and Constant Phase, 377                                   |            |
|            | <i>Saddle points, 377</i>   |            |
|            | <i>Paths of constant level and constant phase, 379</i>  |            |
| <b>4.2</b> | <b>Isolated First-Order Saddle Points, 382</b>  |            |
| 4.2a       | First-Order Approximation, 382  |            |
|            | <i>Analytical details, 383      Examples, 383</i>   |            |
| 4.2b       | Complete Asymptotic Expansion, 384  |            |
| 4.2c       | First-Order, "Stationary Phase" Evaluation of Finite Integrals, 386                                 |            |
|            | <i>Example, 387</i>   |            |
| 4.2d       | Steepest-Descent Evaluation of a Typical Diffraction Integral, 388                                  |            |
| 4.2e       | Integrands with Two Relevant Isolated Saddle Points: Asymptotic Expansion of the Airy Integral, 391 |            |
| <b>4.3</b> | <b>Isolated Saddle Points of Higher Order, 397</b>  |            |
| <b>4.4</b> | <b>First-Order Saddle Point and Nearby Singularities, 399</b>                                       |            |
| 4.4a       | Simple Pole Singularity, 399  |            |
|            | <i>Analytical details, 400</i>  |            |



|                     |   |            |
|---------------------|---|------------|
| 4.4b                | Multiple Pole Singularity, 406  |            |
| 4.4c                | Branch Point Singularity, 407   |            |
| 4.4d                | Uniform Asymptotic Evaluation of a Typical Diffraction Integral, 407            |            |
| <b>4.5</b>          | <b>Nearby First-Order Saddle Points, 410</b>                                    |            |
| 4.5a                | Two Saddle Points, 410  |            |
|                     | <i>Analytical details, 413</i>  |            |
|                     | <i>Example: Asymptotic evaluation of Hankel function, 416</i>                   |            |
| 4.5b                | Three Saddle Points, 419  |            |
| <b>4.6</b>          | <b>Saddle Points Near an Endpoint, 421</b>                                      |            |
| 4.6a                | Single Saddle Point, 421  |            |
| 4.6b                | Two First-Order Saddle Points, 423  |            |
| <b>4.7</b>          | <b>Multiple Integrals, 428</b>  |            |
| <b>4.8</b>          | <b>Integration Around a Branch Point, 429</b>                                   |            |
| <b>Appendix 4A.</b> | <b>Higher-Order Derivatives of <math>G(s) = f(z) dz/ds</math>, 431</b>          |            |
| <b>Appendix 4B.</b> | <b>Properties of the Airy Functions, 432</b>                                    |            |
| <b>5.</b>           | <b>FIELDS IN PLANE-STRATIFIED REGIONS</b>                                       | <b>442</b> |
| <b>5.1</b>          | <b>Introduction, 442</b>  |            |
| <b>5.2</b>          | <b>Field Representations in Regions with Piecewise Constant Properties, 444</b> |            |
| 5.2a                | Derivation of the Time-Harmonic Field From Scalar Potentials, 444               |            |
| 5.2b                | Modal Representations for Unbounded Cross Sections, 446                         |            |
|                     | <i>Point-source excitation, 448</i>   |            |
|                     | <i>Line-source excitation, 449</i>  |            |

5.2c Fields Excited by Impulsive Sources, 450

5.2d Fields Excited by Charges in Uniform Rectilinear Motion, 453

### 5.3 Integration Techniques, 455

5.3a Analytical Properties of the Representation Integrals, 455

5.3b Definition of  $\kappa(\xi) = \sqrt{k^2 - \xi^2}$  in the Complex  $\xi$ -Plane, 459

5.3c The Transformation  $\xi = k \sin w$ , 462

5.3d Asymptotic Evaluation of a Typical Radiation Integral for the Incident and Reflected Fields, 464

5.3e General Properties of Pole and Branch-Point Wave Contributions, 470

5.3f Asymptotic Evaluation of a Typical Radiation Integral for the Transmitted Fields, 473

### 5.4 Sources in an Unbounded Dielectric, 476

5.4a Dipoles Oriented Along  $z$ , 477

*Time-harmonic electric source current density:  $\hat{\mathbf{J}}(\mathbf{r}, t) = I\delta(\mathbf{r})e^{-i\omega t}\mathbf{z}_0$ , 477 Discussion, 478 Normalization for plane wave incidence, 478 Modal procedure, 479 Alternative representations, 480 Pulsed electric source current density:  $\hat{\mathbf{J}}(\mathbf{r}, t) = \hat{p}\delta(\mathbf{r})(d/dt)\delta(t)\mathbf{z}_0$ , 482 Magnetic dipole source, 483*

5.4b Dipoles Oriented Transverse to  $z$ , 483

*Time-harmonic electric source current density:  $\hat{\mathbf{J}}(\mathbf{r}, t) = I\delta(\mathbf{r})e^{-i\omega t}\mathbf{y}_0$ , 483 Discussion, 484 Time-harmonic magnetic source current density:  $\hat{\mathbf{M}}(\mathbf{r}, t) = VI\delta(\mathbf{r})e^{-i\omega t}\mathbf{y}_0$ , 484 Pulsed electric or magnetic source currents, 484*

5.4c Line Currents Oriented Transverse to  $z$ , 484

*Time-harmonic electric source current density:  $\hat{\mathbf{J}}(\mathbf{r}, t) = I\delta(\hat{\mathbf{p}} - \hat{\mathbf{p}}')e^{-i\omega t}\mathbf{x}_0$ , 484 Normalization for plane wave incidence, 486 Discussion, 486 Modal procedure, 487 Time-harmonic electric source current density:  $\hat{\mathbf{J}}(\mathbf{r}, t) = I\delta(\hat{\mathbf{p}} - \hat{\mathbf{p}}')e^{-i\omega t}\mathbf{z}_0$ , 489 Discussion, 489 Time-harmonic magnetic current density, 490 Pulsed source currents, 490*

5.4d Line Currents Oriented along  $z$ , 491

*Time-harmonic electric current density:*  $\hat{\mathbf{J}}(\mathbf{r}, t) = I\delta(\mathbf{p} - \mathbf{p}') \cdot e^{i\alpha z} e^{-i\omega t} \mathbf{z}_0$ , 491      *Discussion*, 492

5.4e Point Charge in Uniform Straight Motion:  $\hat{\mathbf{J}}(\mathbf{r}, t) = qv\delta(x - vt)\delta(\hat{\mathbf{p}} - \hat{\mathbf{p}}')\mathbf{x}_0$ , 494

*Discussion*, 496      *Modal representation*, 498

## 5.4f Ring Currents, 499

*Time-harmonic longitudinal electric source current density:*  $\hat{\mathbf{J}}(\mathbf{r}, t) = \mathbf{J}^0\delta(\mathbf{p} - \mathbf{p}')\delta(z - z')e^{in\phi} e^{-i\omega t} \mathbf{z}_0$ , 500      *Discussion*, 501      *Modal representation (circular waveguide)*, 504      *Time-harmonic azimuthal electric source current density:*  $\hat{\mathbf{J}}(\mathbf{r}, t) = I\delta(\mathbf{p} - \mathbf{p}')\delta(z - z')e^{in\phi} e^{-i\omega t} \phi_0$ , 505      *Time-harmonic magnetic current distributions*, 506

## 5.5 Sources in the Presence of a Semi-Infinite Dielectric Medium, 506

5.5a Time-Harmonic Longitudinal Electric Current Element:  $\hat{\mathbf{J}}(\mathbf{r}, t) = Il\delta(\mathbf{p})\delta(z - z')e^{-i\omega t} \mathbf{z}_0$ , 506

*Discussion*, 510      *Analytical details*, 514

5.5b Time-Harmonic Transverse Electric Current Element:  $\hat{\mathbf{J}}(\mathbf{r}, t) = Il\delta(\mathbf{p}) \cdot \delta(z - z')e^{-i\omega t} \mathbf{x}_0$ , 521

## 5.5c Time-Harmonic Magnetic Current Element, 523

5.5d Pulsed Longitudinal Electric Current Element:  $\hat{\mathbf{J}}(\mathbf{r}, t) = \hat{p}\delta(\mathbf{p})\delta(z - z') \cdot (d/dt)\delta(t)\mathbf{z}_0$ , 523

*Analytical details*, 525

5.5e Time-Harmonic Transverse Electric Line Current:  $\hat{\mathbf{J}}(\mathbf{r}, t) = I\delta(\hat{\mathbf{p}} - \hat{\mathbf{p}}') \cdot e^{-i\omega t} \mathbf{x}_0$ , 527

*Analytical details*, 529

5.5f Time-Harmonic Transverse Line Distribution of Longitudinally Directed Electric Current Elements:  $\hat{\mathbf{J}}(\mathbf{r}, t) = \mathbf{J}^0\delta(\hat{\mathbf{p}} - \hat{\mathbf{p}}')e^{-i\omega t} \mathbf{z}_0$ , 530

## 5.5g Time-Harmonic Progressively Phased Transverse Electric Line Currents, 530

*Transversely directed current elements:*  $\hat{\mathbf{J}}(\mathbf{r}, t) = I\delta(\hat{\mathbf{p}} - \hat{\mathbf{p}}') \cdot e^{i\alpha x} e^{-i\omega t} \mathbf{x}_0$ , 530      *Longitudinally directed current elements:*  $\hat{\mathbf{J}}(\mathbf{r}, t) = \mathbf{J}^0\delta(\hat{\mathbf{p}} - \hat{\mathbf{p}}')e^{i\alpha x} e^{-i\omega t} \mathbf{z}_0$ , 530

## 5.5h Time-Harmonic Ring Currents, 530

## 5.5i Pulsed Transverse Electric Line Currents, 531

*Analytical details, 532*

## 5.5j Point Charge in Uniform Straight Motion Parallel to Interface, 532

## 5.5k Phenomena in Bounded Regions with Negative Real Dielectric Constant (Time-Harmonic Regime), 535

**5.6 Time-Harmonic Sources in the Presence of a Dielectric Slab, 538**5.6a Longitudinal Electric Current Element:  $\hat{\mathbf{J}}(\mathbf{r}, t) = I l \delta(\mathbf{p}) \delta(z - z') e^{-i\omega t} \mathbf{z}_0$ , 538

*Discussion, 540    Analytical details, 543    Alternative representation (radial transmission formulation), 546*  
*z-domain, 547     $\phi$ -domain, 547    Modifications for an ungrounded slab, 550*

## 5.6b Other Source Configurations, 552

*Transverse electric current element:  $\hat{\mathbf{J}}(\mathbf{r}, t) = I l \delta(\mathbf{p}) \delta(z - z') \cdot e^{-i\omega t} \mathbf{x}_0$ , 552    Transverse electric line current:  $\hat{\mathbf{J}}(\mathbf{r}, t) = I \delta(\hat{\mathbf{p}} - \hat{\mathbf{p}}') e^{-i\omega t} \mathbf{x}_0$ , 553*

**5.7 Time-Harmonic Sources in the Presence of a Constant-Impedance Surface, 554**5.7a Longitudinal Electric Current Element:  $\hat{\mathbf{J}}(\mathbf{r}, t) = I l \delta(\mathbf{p}) \delta(z - z') e^{-i\omega t} \mathbf{z}_0$ , 554

*Discussion, 555    Analytical details, 556*  
*An image formulation, 557*

5.7b Transverse Magnetic Line Current:  $\hat{\mathbf{M}}(\mathbf{r}, t) = V \delta(\hat{\mathbf{p}} - \hat{\mathbf{p}}') e^{-i\omega t} \mathbf{z}_0$ , 559  
*Alternative representation, 561*

## 5.7c Other Elementary Source Configurations, 562

5.7d Continuous Distribution of Transverse Magnetic Line Currents, 562  
*Excitation of surface waves by an aperture, 562*  
*Radiation from a terminated reactive surface—comparison of various approximations, 564***5.8 Sources in the Presence of Media with Continuous Planar Stratification—Arbitrary Profiles, 571**

## 5.8a General Field Properties, 571

|      |   |
|------|---|
| 5.8b | Derivation of the Time-Harmonic Field from Scalar Potentials, 572   |
| 5.8c | Direct Ray-Optical Solution in a Slowly Varying Medium, 575<br><i>Ray trajectories, 575      Phase change along a ray, 577</i><br><i>Excitation by a transverse electric line current, 578</i><br><i>Excitation by a longitudinal electric current element, 581</i><br><i>Excitation by an incident plane wave, 581</i> |
| 5.8d | Asymptotic Evaluation of a Typical Radiation Integral for a Medium with Monotonic Variation, 583<br><i>Excitation by an electric line current, 585</i><br><i>Asymptotic evaluation, 586      Evaluation near the caustic, 590</i>   |
| 5.8e | Propagation in Ducts—Guided Modes, 592  |
| 5.9  | Sources in the Presence of Media with Continuous Planar Stratification—Special Profiles, 594  |
| 5.9a | Inverse Square Profile, 595<br><i>Properties of the medium, 595      Solution for excitation by a longitudinal magnetic dipole or by a transverse electric line current, 597      Asymptotic evaluation, 599</i><br><i>Ray-optical interpretation, 601</i><br><i>The geometric-optical ray configuration, 606</i>       |
| 5.9b | Radiation in a Duct, 606<br><i>The guided mode spectrum, 606      Radiation from a line source, 608      The guided-mode expansion, 610</i><br><i>The geometric-optical series, 610</i>   |
| 5.9c | An Equivalence Relation for Fields in a Homogeneous and an Inverse Square Medium, 613   |
| 5.9d | Continuous Transition (Epstein Profile), 619  |
| 6.   | <b>FIELDS IN CYLINDRICAL AND SPHERICAL REGIONS 630</b>  |
| 6.1  | <b>Distinctive Field Characteristics, 630</b>   |
| 6.2  | <b>Green's Function Representations in Cylindrical Regions, 633</b>   |
| 6.2a | Derivation of the Field From Scalar Potentials, 633   |

- 6.2b Angular Transmission Representation, 635
  - Time-harmonic line source, 636*
  - Time-harmonic point source, 636*
  - Impulsive line source, 637      Impulsive point source, 637*
  - Plane wave incidence, 637*

### 6.3 Wedge-Type Problems—Integration Techniques, 639

- 6.3a Time-Harmonic Line Source Excitation, 639
  - Solution in integral form, 639*
  - Asymptotic approximation, 641*
  - Transition effects (uniform asymptotic formulation), 643*
- 6.3b Time-Harmonic Plane Wave and Point Source Excitations, 645
  - Solutions in integral form, 645*
  - Asymptotic evaluation, 646*
- 6.3c Pulsed Source Configurations, 647

### 6.4 Perfectly Absorbing Wedge, 650

- 6.4a Time-Harmonic Line Source Excitation, 651
  - Higher-order terms in the asymptotic expansion, 653*
- 6.4b Impulsive Line Source Excitation, 654
- 6.4c Time-Harmonic Point Source Excitation, 656
- 6.4d Impulsive Point Source Excitation, 657
- 6.4e Time-Harmonic Plane Wave Excitation, 657
- 6.4f Impulsive Plane Wave Excitation, 659

### 6.5 Perfectly Conducting Wedge and Half Plane, 660

- 6.5a Angular Transmission Representation, 660
- 6.5b Radial Transmission Representation, 663
- 6.5c Time-Harmonic Line Source Excitation, 664
- 6.5d Impulsive Line Source Excitation, 666
- 6.5e Time-Harmonic Point Source Excitation, 667

- 6.5f Impulsive Point Source Excitation, 668
- 6.5g Time-Harmonic Plane Wave Excitation, 669
- 6.5h Impulsive Plane Wave Excitation, 670
- 6.5i Special Case: The Half-Plane, 670
  - Time-harmonic line-source excitation, 671    Impulsive line-source excitation, 671    Time-harmonic point-source excitation, 672    Impulsive point-source excitation, 673    Time-harmonic plane-wave excitation, 673    Impulsive plane-wave excitation, 673*
- 6.6 Wedge with Variable Impedance Walls, 674
  - 6.6a One Perfectly Absorbing and One Variable-Impedance Wall, 675
    - Representation emphasizing quasi-optic properties, 675*
    - Asymptotic evaluation, 677    Representation emphasizing guided-wave properties: surface wave, 681*
  - 6.6b Two Variable-Impedance Walls, 683
- 6.7 Diffraction by a Circular Cylinder, 685
  - 6.7a Line-Source Excitation, 685
    - The residue series—physical interpretation, 691*
    - Illuminated region—geometric-optical field, 693*
  - 6.7b Point-Source Excitation, 697
- 6.8 Fields in Spherical Regions, 698
  - 6.8a Introduction, 698
  - 6.8b Alternative Field Representations, 699
    - Free space, 699    The sphere, 701    The cone, 703*
  - 6.8c The Cone—Diffracted Field at High Frequencies, 705
    - Asymptotic expansion, 705*
    - Approximation for small cone angles, 707*
- Appendix 6A. Asymptotic Formulas for  $H_v^{(1)}(z)$  and  $H_v^{(2)}(z)$ , 710
  - 6A.1 Large, Unequal Order and Argument, 710

6A.2 Large Argument, 712

6A.3 Large Order, 713

6A.4 Large and Almost Equal Order and Argument, 715

6A.5 The Zeros of  $H_v^{(1)}(z)$ ,  $H_v^{(1)}(z)$ , and Related Results, 716

Appendix 6B. Miscellaneous Formulas Involving Cylinder Functions, 718

## 7. FIELDS IN UNIAXIALLY ANISOTROPIC REGIONS

740

7.1 Introduction, 740

7.2 Network Formulation of Field Problem, 745

7.2a Derivation of the Transmission Line Equations, 745

7.2b Formulation in Terms of Potential Functions, 749

7.2c The Dyadic Green's Functions, 750

*General case, 750      Longitudinal sources, 752*

*Piecewise constant media, 752      Isotropic media, 753*

7.3 Sources in Unbounded Media, 753

7.3a Dipoles Oriented along Optic Axis, 754

*Time-harmonic electric source current density:  $\hat{\mathbf{J}}(\mathbf{r}, t) = I\delta(\mathbf{r})e^{-i\omega t}\mathbf{z}_0$ , 754      Modal procedure, 756*

*Time-harmonic magnetic source current density:  $\hat{\mathbf{M}}(\mathbf{r}, t) = VI\delta(\mathbf{r})e^{-i\omega t}\mathbf{z}_0$ , 762*

7.3b Dipoles Oriented Transverse to Optic Axis, 762

*Time-harmonic electric source current density:  $\hat{\mathbf{J}}(\mathbf{r}, t) = I\delta(\mathbf{r})e^{-i\omega t}\mathbf{x}_0$ , 762      Time-harmonic magnetic source current density:  $\hat{\mathbf{M}}(\mathbf{r}, t) = VI\delta(\mathbf{r})e^{-i\omega t}\mathbf{x}_0$ , 763*

7.3c Linearly Phased Line Currents Oriented along Optic Axis, 763

*Time-harmonic electric source current density:  $\hat{\mathbf{J}}(\mathbf{r}, t) = Ie^{iaz}\delta(\mathbf{p})e^{-i\omega t}\mathbf{z}_0$ , 763      Time-harmonic magnetic source current density:  $\hat{\mathbf{M}}(\mathbf{r}, t) = Ve^{iaz}\delta(\mathbf{p})e^{-i\omega t}\mathbf{z}_0$ , 766*

7.3d Point Charge in Uniform Straight Motion along Optic Axis, 766



### 7.3e Line Currents Oriented Perpendicular to Optic Axis, 767

*Magnetic source current density:  $\hat{\mathbf{M}}(\mathbf{r}, t) =$*

*$V\delta(\hat{\mathbf{p}} - \hat{\mathbf{p}}')e^{-i\omega t}\mathbf{x}_0$ , 767*

*Removal of the infinity in the radiated power, 769*

*Electric line source current density:  $\hat{\mathbf{J}}(\mathbf{r}, t) =$*

*$I\delta(\hat{\mathbf{p}} - \hat{\mathbf{p}}')e^{-i\omega t}\mathbf{x}_0$ , 771*

*Electric dipolar source current density:  $\hat{\mathbf{J}}(\mathbf{r}, t) =$*

*$A\delta(\hat{\mathbf{p}} - \hat{\mathbf{p}}')e^{-i\omega t}(\mathbf{y}_0 \cos \alpha + \mathbf{z}_0 \sin \alpha)$ , 771*

*Highly directive, distributed magnetic current source, 772*

## 7.4 Diffraction by Structures Embedded in an Infinite Homogeneous Plasma, 776

### 7.4a Optic Axis Parallel to Axis of a Perfectly Conducting Cylindrical Obstacle, 776

### 7.4b Optic Axis Perpendicular to Axis of a Perfectly Conducting Cylindrical Obstacle, 776

*Formulation and reduction of the boundary value problem, 776*

### 7.4c Half Space Bounded by a Perfect Conductor, 779

### 7.4d Half Space Bounded by a Reactive Surface, 781

### 7.4e Wedge and Half Plane, 783

## 7.5 Radiation from a Homogeneous Plasma Half Space, 787

### 7.5a Formulation of the Problem (Line-Source Excitation), 788

### 7.5b Reflection and Transmission of Plane Waves, and the Radiation Condition, 789

### 7.5c Modal Representation of the Solution, 793

### 7.5d Asymptotic Evaluation in the Plasma Half Space, 794

*The geometric-optical field, 796      The lateral waves, 799*

*Fields in the vicinity of the angle of total reflection, 802*

### 7.5e Asymptotic Evaluation in the Vacuum Half Space, 806

*Ray interpretation of the saddle point condition—caustic and cusp, 806      Asymptotic field evaluation, 808*

### 7.5f Radiation from a Transverse Electric Dipole, 813

**8. FIELDS IN ANISOTROPIC REGIONS****821****8.1 Introduction, 821****8.2 Guided Wave Representation in Anisotropic Media (Reduced Formulation), 823**

8.2a Formulation for Arbitrary Media, 823

8.2b Lossless Regions, 826

8.2c Lossy (Symmetric) Regions, 827

8.2d Transverse anisotropy (Reflection Symmetry), 827

8.2e Isotropic Regions, 828

8.2f Regions with  $E$ - and  $H$ -Mode Decompositions, 829

8.2g Modal Representations for the Reduced Electromagnetic Field, 831

8.2h Non-Conventional Transmission Line Descriptions, 832

**8.3 Guided Waves in a Cold Magnetoplasma (Guide Axis Parallel to Gyrotropic Axis), 832**

8.3a Evaluation of the Mode Functions, 837

8.3b Wavenumber Surfaces, 843

8.3c Green's Functions for Unbounded Regions, 846

*Modal representation, 846**Asymptotic evaluation of far fields, 849**Transition region: coalescence of two saddle points, 853**Transition region: saddle point moves to infinity, 854*

8.3d Green's Functions for Plane-Stratified Regions, 855

*Representation in terms of ordinary and extraordinary modes, 855**Asymptotic evaluation of the fields, 857***8.4 Guided Waves in a Cold Magnetoplasma (Guide Axis Perpendicular to Gyrotropic Axis), 860**8.4a Eigenfunctions and Eigenvalues for  $\mathbf{b}_0$  Perpendicular to  $\mathbf{z}_0$ , 860

- 8.4b Two-Dimensional Boundary Value Problems in Gyrotropic Media, 862
- 8.4c Radiation from a Magnetic Line Source in the Presence of a Perfectly Conducting Plane, 864  
*Unidirectional surface wave, 866      The far field, 868*
- 8.4d Diffraction by a Half-Plane, 869

**SUBJECT INDEX****877****AUTHOR INDEX****885**

