

Contents

CHAPTER I

THE ELECTROMAGNETIC SPECTRUM

1

Part I. Historical Introduction

1.1 Electromagnetic waves, 1; 1.2 Optics, 1; 1.3 The discovery of electric oscillations, 4; 1.4 The discovery of electromagnetic waves, 5; 1.5 The expansion of the spectrum, 7.

Part II. Generation and Detection of Electromagnetic Waves

1.6 Sources of electromagnetic waves, 9; 1.7 Detectors of electromagnetic waves, 15.

Part III. Properties of Electromagnetic Radiations

1.8 Electromagnetic waves, 22; 1.9 The Doppler effect, 26; 1.10 Quantum nature of electromagnetic radiations, 31; 1.11 The unity of the electromagnetic spectrum, 33.

CHAPTER II

WAVE PROPAGATION

35

2.1 Radiation from an accelerated charge, 35; 2.2 Simple harmonic motion, 42; 2.3 Graphical description of simple harmonic waves, 44; 2.4 Equation of wave motion, 46; 2.5 Vector representation of amplitude and phase, 47; 2.6 Complex numbers. A simple representation of vectors, 48; 2.7 Intensity of radiation, 50; 2.8 Velocity, a function of the physical properties of the medium, 51; 2.9 Reversibility of waves, 53.

CHAPTER III

SUPERPOSITION OF WAVES

57

3.1 The principle of superposition, 57; 3.2 Superposition of waves of the same frequency, 58; 3.3 Composition of simple harmonic motions,

SUPERPOSITION OF WAVES (*Continued*)

59; 3.4 *Incoherent sources*, 60; 3.5 *Coherent sources*, 62; 3.6 *Superposition of perpendicular simple harmonic motions*, 63; 3.7 *Compound waves*, 64; 3.8 *Composition of spectral lines*, 66; 3.9 *Group velocity*, 70.

CHAPTER IV

THE VELOCITY OF LIGHT 76

4.1 *The next decimal place*, 76; 4.2 *Romer's method*, 77; 4.3 *Bradley's method*, 79; 4.4 *Terrestrial methods of Fizeau and Foucault*, 81; 4.5 *Michelson's method*, 83; 4.6 *Electro-optical shutter method*, 84; 4.7 *Bergstrand's method*, 88; 4.8 *The velocity of microwaves*, 89; 4.9 *Re-evaluation*, 90.

CHAPTER V

STANDING WAVES 92

5.1 *The measurement of wavelengths*, 92; 5.2 *Equation of a standing wave*, 92; 5.3 *Demonstration of standing waves on an oscilloscope*, 94; 5.4 *Standing microwaves in free space*, 95; 5.5 *Oblique incidence upon a mirror*, 97; 5.6 *Wave guides*, 98; 5.7 *Standing waves along a transmission line*, 100; 5.8 *Standing waves in a coaxial line*, 103; 5.9 *Standing light waves*, 106.

CHAPTER VI

INTERFERENCE OF WAVES FROM TWO SECONDARY SOURCES 108

6.1 *Interference between two spherical waves*, 108; 6.2 *Interference between a plane wave and a spherical wave*, 113; 6.3 *Interference between a plane wave and reradiation from a resonant metal rod*, 118; 6.4 *Interference between a plane wave and a cylindrical wave*, 121; 6.5 *Young's experiment*, 123; 6.6 *Fresnel's biprism, Fresnel's mirrors, and Lloyd's mirror*, 126; 6.7 *Young's experiment with microwaves*, 128; 6.8 *Radio fading*, 131; 6.9 *Direction finder*, 132.

CHAPTER VII

MICHELSON'S INTERFEROMETER 135

7.1 *Michelson's interferometer in optics*, 135; 7.2 *Structure of Michelson's interferometer*, 136; 7.3 *Adjustment of Michelson's interferometer*, 137; 7.4 *Measurement of wavelength difference*, 140; 7.5 *Comparison of wavelengths with the standard meter*, 142; 7.6 *Twyman and Green interferometer*, 145; 7.7 *Michelson-Morley experiment*,

MICHELSON'S INTERFEROMETER (*Continued*)

147; 7.8 *Measurement of index of refraction*, 150; 7.9 *Measurement of index of refraction of gas*, 152; 7.10 *Michelson's interferometer with microwaves*, 153; 7.11 *The identity of Wheatstone's bridge and Michelson's interferometer*, 155.

CHAPTER VIII

INTERFERENCE IN THIN FILMS**159**

8.1 *Films in optics*, 159; 8.2 *Interference of reflected waves*, 159; 8.3 *Extended sources*, 164; 8.4 *Interference of transmitted waves*, 166; 8.5 *Thin films for microwaves*, 169; 8.6 *Interference films on glass*, 171; 8.7 *Step gage*, 176; 8.8 *Interference filters, transmission*, 180; 8.9 *Interference filters, reflection*, 182; 8.10 *Newton's rings*, 185; 8.11 *Fabry-Perot interferometer*, 189; 8.12 *Lummer-Gehrke plate*, 194.

CHAPTER IX

FRAUNHOFER DIFFRACTION**197**

9.1 *Diffraction*, 197; 9.2 *Fraunhofer diffraction*, 198; 9.3 *Diffraction by a single slit*, 198; 9.4 *Diffraction by a circular aperture*, 204; 9.5 *Minimum angle of resolution*, 206; 9.6 *Chromatic resolving power of a prism*, 209; 9.7 *Diffraction by a double slit*, 213; 9.8 *Double slit with microwaves*, 217; 9.9 *Two sources, Michelson's stellar interferometer*, 218; 9.10 *Size of source*, 223.

CHAPTER X

DIFFRACTION GRATING**227**

10.1 *Measurement of wavelengths with gratings*, 227; 10.2 *Fraunhofer diffraction by a grating*, 228; 10.3 *Diffraction pattern of a grating*, 231; 10.4 *Chromatic resolving power*, 234; 10.5 *Echelon gratings, use of high orders*, 236; 10.6 *Oblique incidence, minimum deviation*, 237; 10.7 *Reflection gratings for x-rays*, 240; 10.8 *focusing reflection gratings for the ultraviolet*, 241; 10.9 *Echelette gratings for the infrared*, 243; 10.10 *Fraunhofer diffraction by two-dimensional gratings*, 245; 10.11 *Fraunhofer diffraction by three-dimensional gratings*, 250.

CHAPTER XI

FRESNEL DIFFRACTION**256**

11.1 *The Fresnel method*, 256; 11.2 *Kirchhoff's method*, 258; 11.3 *Diffraction of spherical waves by a circular aperture*, 264; 11.4 *Diffraction of a plane wave by a circular aperture*, 266; 11.5 *Microwave*

FRESNEL DIFFRACTION (*Continued*)

demonstrations of Fresnel diffraction, 272; 11.6 Far field diffraction, Fresnel zone methods, 276; 11.7 Diffraction pattern of a cylindrical wave by a straight edge, 283; 11.8 Diffraction pattern of slits, 292; 11.9 Diffraction pattern of an opaque strip, 294; 11.10 Babinet's principle, 295; 11.11 Geometrical optics, a special case of physical optics, 297.

CHAPTER XII

DIFFRACTION OF TRANSVERSE WAVES **300**

12.1 Young's method, 300; 12.2 Diffraction pattern in the plane of a circular aperture, 301; 12.3 Diffraction pattern on the axis of a circular aperture, 305; 12.4 Diffraction pattern on the axis of a ring opening, 308; 12.5 Fraunhofer diffraction by a single slit, Young's method, 309; 12.6 Fraunhofer diffraction by a grating, Young's method, 310; 12.7 Diffraction pattern in the plane of a half-screen, 312; 12.8 Total diffraction pattern of a half-screen, 315; 12.9 Small apertures, 328; 12.10 Trends in diffraction studies, 331.

CHAPTER XIII

ELECTROMAGNETIC THEORY **335**

13.1 Light as a branch of electricity and magnetism, 335; 13.2 Gauss' law, 336; 13.3 Ampere's law in circuital form, 338; 13.4 Displacement current, 340; 13.5 Faraday's law of induced electromotive force, 341; 13.6 The wave equations, 343; 13.7 The interdependence of the electric and magnetic waves, 345; 13.8 The flux of energy, 349; 13.9 Applications and limitations, 350.

CHAPTER XIV

ABSORPTION OF ELECTROMAGNETIC WAVES **352**

14.1 Bougier's law, 352; 14.2 True absorption, 354; 14.3 Scattering, 355; 14.4 Compton scattering, 357; 14.5 Resonance, 359; 14.6 Fluorescence, 361; 14.7 Fluorescence absorption of x-rays, 361; 14.8 Raman scattering, 365.

CHAPTER XV

DISPERSION **368**

15.1 Newton's treatment of color aberration, 368; 15.2 Normal dispersion by transparent dielectrics, 369; 15.3 Anomalous dispersion, 370; 15.4 The developing theory of dispersion, 373; 15.5 Dispersion of microwaves, 374; 15.6 Mechanical analogue of the forced electric

DISPERSION (*Continued*)

oscillation, 375; 15.7 Forced oscillation of a dipole, 379; 15.8 The index of refraction of a dielectric, 381; 15.9 Indices of refraction in spectral regions of low absorption, 383; 15.10 Index of refraction in the region of an absorption line, 383.

CHAPTER XVI

POLARIZATION**388**

16.1 Sources of polarized electromagnetic waves, 388; 16.2 Polarizing devices, 392; 16.3 Polarization of microwaves, 393; 16.4 Polarization by parallel wires, 394; 16.5 Polarization by reflection from dielectrics, 396; 16.6 Theory of reflection and refraction, 398; 16.7 Interpretation of Fresnel's equations, 404; 16.8 Incidence from the side of the more dense medium, 408; 16.9 Reflection from metals, 414; 16.10 Interference of incident and reflected microwaves. Electric field in the plane of incidence, 416; 16.11 Optical properties of metals, 417; 16.12 Selective reflection, 423; 16.13 Polarization by scattering, 424.

CHAPTER XVII

DOUBLE REFRACTION**428**

17.1 Observation of double refraction in calcite, 428; 17.2 Definition of a plane of reference in the calcite, 429; 17.3 Polarization of the doubly refracted rays, 430; 17.4 Applications of Huygens' principle to double refraction, 432; 17.5 Measurement of principal indices of refraction of uniaxial crystals, 435; 17.6 Polarizing devices made by cutting and splicing uniaxial crystals, 436; 17.7 Huygens wavelets in biaxial crystals, 438; 17.8 Internal conical refraction, 442; 17.9 The Fresnel ellipsoid, 445.

CHAPTER XVIII

ELLIPTICAL POLARIZATION**449**

18.1 Elliptical oscillations of electric fields, 449; 18.2 Elliptically polarized microwaves, 450; 18.3 Elliptical polarization by double refraction, 451; 18.4 Interference of polarized light, 454; 18.5 Simple analysis of polarized light, 456; 18.6 Babinet compensator, 457; 18.7 Kerr effect, 459; 18.8 Double refraction by mechanical strain, 460; 18.9 Dispersion by double refraction, 461; 18.10 Convergent polarized light in crystals, 462.

CHAPTER XIX

ROTATION OF THE PLANE OF POLARIZATION 466

19.1 Rotation of the plane of polarization by liquids, 466; 19.2 Rotation of the plane of polarization of microwaves, 467; 19.3 Rotation of the plane of polarization by quartz, 470; 19.4 Fresnel's analysis of optical activity, 470; 19.5 Rotatory dispersion, 473; 19.6 The Faraday effect, 474; 19.7 The Faraday effect of microwaves, 475.

APPENDIX I

DIFFERENTIAL EQUATION OF LONGITUDINAL WAVES 479

APPENDIX II

DERIVATION OF KIRCHHOFF'S FORMULATION OF FRESNEL'S THEORY OF DIFFRACTION 483

Table I Fresnel Integrals, 488; Table II Bessel Integrals, 489.

ANSWERS TO ALTERNATE PROBLEMS 490**INDEX 493**