FRANCIS A. JENKINS

HARVEY E. WHITE

Fundamentals of Optics

FOURTH EDITION

INTERNATIONAL STUDENT EDITION

McGRAW-HILL KOGAKUSHA, LTD.
Tokyo
Auckland
Düsseldorf
Johannesburg
London
Mexico
New Delhi
Panama
São Paulo
Singapore
Sydney

FRANCIS A. JENKINS
Late Professor of Physics
University of California, Berkeley

HARVEY E. WHITE
Professor of Physics, Emeritus
Director of the Lawrence Hall of Science, Emeritus
University of California, Berkeley

Fundamentals of Optics

FOURTH EDITION

Library of Congress Cataloging in Publication Data

Jenkins, Francis Arthur, dates
Fundamentals of optics.

First ed. published in 1937 under title: Fundamentals of physical optics.
Includes index.
1. Optics. I. White, Harvey Elliott, date joint author. II. Title.
QC355.2.J46 1976 535 75-26989
ISBN 0-07-032330-5

FUNDAMENTALS
OF OPTICS

INTERNATIONAL STUDENT EDITION

Exclusive rights by McGraw-Hill Kogakusha, Ltd. for manufacture and export. This book cannot be re-exported from the country to which it is consigned by McGraw-Hill.

I

Copyright © 1957, 1976 by McGraw-Hill, Inc. All rights reserved.
Copyright 1950 by McGraw-Hill, Inc. All rights reserved.
Formerly published under the title of FUNDAMENTALS OF PHYSICAL OPTICS, copyright 1937 by McGraw-Hill, Inc.
Copyright renewed 1965 by Francis A. Jenkins and Harvey E. White.
No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of the publisher.

PRINTED IN JAPAN

PREFACE TO THE FOURTH EDITION

This fourth edition is written primarily to be used as a textbook by college students majoring in one of the physical sciences. The first, second, and third editions were written by Francis A. Jenkins and Harvey E. White while teaching optics in the physics department at the University of California, Berkeley. With the passing of Professor Jenkins in 1960 this fourth edition has been revised by Harvey E. White.

A considerable number of innovative ideas and new concepts have been developed in the field of optics since the third edition was published in 1957, thereby requiring a sizable amount of new material. Three new chapters, a number of new sections on modern optics, a number of new references, and all new problems at the ends of all chapters have been added to bring the fourth edition up to date.

Fizeau's experiments on the speed of light in air and Foucault's experiments on the speed of light in stationary matter have been moved to Chapter 1. This serves as a better introduction to the important concept of refractive index and leaves the rest of Chapter 19 relatively unchanged.

In Part One, Geometrical Optics, the long and tedious calculations of ray tracing, using logarithms, has been replaced by direct calculations using the relatively new electronic calculators, thereby permitting lens design engineers to program larger computers.

In Part Two, Wave Optics, Chapter 11 has been modified to give a better approach to the subject of wave motion. In Chapter 16 a section has been added on the correlation interferometer. Some of the major features of recent developments have been added at the end of Chapter 28: modern wave optics, spatial filtering, the phase-contrast microscope, and schlieren optics.

In Part Three, Quantum Optics, three new chapters have been added as important new developments: Chapter 29, Light Quanta and Their Origin; Chapter 30, Lasers; and Chapter 31, Holography.

I wish to take this opportunity of thanking Dr. Donald H. White for his assistance in gathering much of the new material used in this the fourth edition.

HARVEY E. WHITE

此为试读,需要完整PDF请访问: www.ertongbook.com

PREFACE TO THE THIRD EDITION

The chief objectives in preparing this new edition have been simplification and modernization. Experience on the part of the authors and of the many other users of the book over the last two decades has shown that many passages and mathematical derivations were overly cumbersome, thereby losing the emphasis they should have had. As an example of the steps taken to rectify this defect, the chapter on reflection has been entirely rewritten in simpler form and placed ahead of the more difficult aspects of polarized light. Furthermore, by expressing frequency and wavelength in circular measure, and by introducing the complex notation in a few places, it has been possible to abbreviate the derivations in wave theory to make room for new material.

In any branch of physics fashions change as they are influenced by the development of the field as a whole. Thus, in optics the notions of wave packet, line width, and coherence length are given more prominence because of their importance in quantum mechanics. For the same reason, our students now usually learn to deal with complex quantities at an earlier stage, and we have felt justified in giving some examples of how helpful these can be. Because of the increasing use of concentric optics, as well as graphical methods of ray tracing, these subjects have been introduced in the chapters on geometrical optics. The elegant relationships between geometrical optics and particle mechanics, as in the electron microscope and quadrupole lenses,

could not be developed because of lack of space; the instructor may wish to supplement the text in this direction. The same may be true of the rather too brief treatments of some subjects where old principles have recently come into prominence, as in Čerenkov radiation, the echelle grating, and multilayer films.

A difficulty that must present itself to the authors of all textbooks at this level is that of avoiding the impression that the subject is a definitive, closed body of knowledge. If the student can be persuaded to read the original literature to any extent, this impression soon fades. To encourage such reading, we have inserted many references, to original papers as well as to books, throughout the text. An entirely new set of problems, representing a rather greater spread of difficulty than heretofore, is included.

It is not possible to mention all those who have assisted us by suggestions for improvement. Specific errors or omissions have been pointed out by L. W. Alvarez, W. A. Bowers, J. E. Mack, W. C. Price, R. S. Shankland, and J. M. Stone, while H. S. Coleman, J. W. Ellis, F. S. Harris, Jr., R. Kingslake, C. F. J. Overhage, and R. E. Worley have each contributed several valuable ideas. We wish to express our gratitude to all of these, as well as to T. L. Jenkins, who suggested the simplification of certain derivations and checked the answers to many of the problems.

FRANCIS A. JENKINS
HARVEY E. WHITE

CONTENTS

	Preface to the Fourth Edition	xvii
	Preface to the Third Edition	xix
Part One	**Geometrical Optics**	
1	**Properties of Light**	**3**
1.1	The Rectilinear Propagation of Light	5
1.2	The Speed of Light	6
1.3	The Speed of Light in Stationary Matter	8
1.4	The Refractive Index	9
1.5	Optical Path	10
1.6	Laws of Reflection and Refraction	11
1.7	Graphical Construction for Refraction	13
1.8	The Principle of Reversibility	14
1.9	Fermat's Principle	14
1.10	Color Dispersion	18

2	**Plane Surfaces and Prisms**	**24**
2.1	Parallel Beam	24
2.2	The Critical Angle and Total Reflection	25
2.3	Plane-Parallel Plate	28
2.4	Refraction by a Prism	29
2.5	Minimum Deviation	30
2.6	Thin Prisms	32
2.7	Combinations of Thin Prisms	32
2.8	Graphical Method of Ray Tracing	33
2.9	Direct-Vision Prisms	34
2.10	Reflection of Divergent Rays	36
2.11	Refraction of Divergent Rays	36
2.12	Images Formed by Paraxial Rays	38
2.13	Fiber Optics	40
3	**Spherical Surfaces**	**44**
3.1	Focal Points and Focal Lengths	45
3.2	Image Formation	46
3.3	Virtual Images	47
3.4	Conjugate Points and Planes	47
3.5	Convention of Signs	50
3.6	Graphical Constructions. The Parallel-Ray Method	50
3.7	Oblique-Ray Methods	52
3.8	Magnification	54
3.9	Reduced Vergence	54
3.10	Derivation of the Gaussian Formula	56
3.11	Nomography	57
4	**Thin Lenses**	**60**
4.1	Focal Points and Focal Lengths	60
4.2	Image Formation	62
4.3	Conjugate Points and Planes	62
4.4	The Parallel-Ray Method	62
4.5	The Oblique-Ray Method	63
4.6	Use of the Lens Formula	64
4.7	Lateral Magnification	64
4.8	Virtual Images	65
4.9	Lens Makers' Formula	67
4.10	Thin-Lens Combinations	68
4.11	Object Space and Image Space	70
4.12	The Power of a Thin Lens	70
4.13	Thin Lenses in Contact	71
4.14	Derivation of the Lens Formula	72
4.15	Derivation of the Lens Makers' Formula	73

5	**Thick Lenses**	**78**
5.1	Two Spherical Surfaces	78
5.2	The Parallel-Ray Method	79
5.3	Focal Points and Principal Points	81
5.4	Conjugate Relations	82
5.5	The Oblique-Ray Method	82
5.6	General Thick-Lens Formulas	84
5.7	Special Thick Lenses	88
5.8	Nodal Points and Optical Center	88
5.9	Other Cardinal Points	90
5.10	Thin-Lens Combination as a Thick Lens	91
5.11	Thick-Lens Combinations	93
5.12	Nodal Slide	93
6	**Spherical Mirrors**	**98**
6.1	Focal Point and Focal Length	98
6.2	Graphical Constructions	99
6.3	Mirror Formulas	102
6.4	Power of Mirrors	104
6.5	Thick Mirrors	105
6.6	Thick-Mirror Formulas	107
6.7	Other Thick Mirrors	109
6.8	Spherical Aberration	109
6.9	Astigmatism	111
7	**The Effects of Stops**	**115**
7.1	Field Stop and Aperture Stop	115
7.2	Entrance and Exit Pupils	116
7.3	Chief Ray	117
7.4	Front Stop	117
7.5	Stop between Two Lenses	118
7.6	Two Lenses with No Stop	120
7.7	Determination of the Aperture Stop	121
7.8	Field of View	122
7.9	Field of a Plane Mirror	122
7.10	Field of a Convex Mirror	124
7.11	Field of a Positive Lens	124
8	**Ray Tracing**	**130**
8.1	Oblique Rays	130
8.2	Graphical Method for Ray Tracing	131
8.3	Ray-tracing Formulas	134
8.4	Sample Ray-tracing Calculations	135

9	**Lens Aberrations**	**149**
9.1	Expansion of the Sine. First-Order Theory	150
9.2	Third-Order Theory of Aberrations	151
9.3	Spherical Aberration of a Single Surface	152
9.4	Spherical Aberration of a Thin Lens	153
9.5	Results of Third-Order Theory	157
9.6	Fifth-Order Spherical Aberration	160
9.7	Coma	162
9.8	Aplanatic Points of a Spherical Surface	166
9.9	Astigmatism	167
9.10	Curvature of Field	170
9.11	Distortion	171
9.12	The Sine Theorem and Abbe's Sine Condition	173
9.13	Chromatic Aberration	176
9.14	Separated Doublet	182
10	**Optical Instruments**	**188**
10.1	The Human Eye	188
10.2	Cameras and Photographic Objectives	191
10.3	Speed of Lenses	191
10.4	Meniscus Lenses	193
10.5	Symmetrical Lenses	193
10.6	Triplet Anastigmats	194
10.7	Telephoto Lenses	195
10.8	Magnifiers	195
10.9	Types of Magnifiers	198
10.10	Spectacle Lenses	198
10.11	Microscopes	200
10.12	Microscope Objectives	201
10.13	Astronomical Telescopes	202
10.14	Oculars and Eyepieces	205
10.15	Huygens Eyepiece	205
10.16	Ramsden Eyepiece	206
10.17	Kellner or Achromatized Ramsden Eyepiece	206
10.18	Special Eyepieces	206
10.19	Prism Binoculars	207
10.20	The Kellner-Schmidt Optical System	208
10.21	Concentric Optical Systems	209
Part Two	**Wave Optics**	
11	**Vibrations and Waves**	**214**
11.1	Simple Harmonic Motion	216
11.2	The Theory of Simple Harmonic Motion	217
11.3	Stretching of a Coiled Spring	218
11.4	Vibrating Spring	221

此为试读,需要完整PDF请访问: www.ertongbook.com

11.5	Transverse Waves	223
11.6	Sine Waves	224
11.7	Phase Angles	225
11.8	Phase Velocity and Wave Velocity	228
11.9	Amplitude and Intensity	229
11.10	Frequency and Wavelength	232
11.11	Wave Packets	235
12	**The Superposition of Waves**	**238**
12.1	Addition of Simple Harmonic Motions along the Same Line	239
12.2	Vector Addition of Amplitudes	240
12.3	Superposition of Two Wave Trains of the Same Frequency	242
12.4	Superposition of Many Waves with Random Phases	244
12.5	Complex Waves	246
12.6	Fourier Analysis	248
12.7	Group Velocity	250
12.8	Graphical Relation between Wave and Group Velocity	252
12.9	Addition of Simple Harmonic Motions at Right Angles	253
13	**Interference of Two Beams of Light**	**259**
13.1	Huygens' Principle	260
13.2	Young's Experiment	261
13.3	Interference Fringes from a Double Source	263
13.4	Intensity Distribution in the Fringe System	265
13.5	Fresnel's Biprism	266
13.6	Other Apparatus Depending on Division of the Wave Front	268
13.7	Coherent Sources	270
13.8	Division of Amplitude. Michelson Interferometer	271
13.9	Circular Fringes	273
13.10	Localized Fringes	275
13.11	White-Light Fringes	276
13.12	Visibility of the Fringes	277
13.13	Interferometric Measurements of Length	279
13.14	Twyman and Green Interferometer	281
13.15	Index of Refraction by Interference Methods	282
14	**Interference Involving Multiple Reflections**	**286**
14.1	Reflection from a Plane-Parallel Film	288
14.2	Fringes of Equal Inclination	291
14.3	Interference in the Transmitted Light	292
14.4	Fringes of Equal Thickness	293
14.5	Newton's Rings	294
14.6	Nonreflecting Films	295
14.7	Sharpness of the Fringes	297
14.8	Method of Complex Amplitudes	299
14.9	Derivation of the Intensity Function	300

14.10	Fabry-Perot Interferometer	301
14.11	Brewster's Fringes	302
14.12	Chromatic Resolving Power	303
14.13	Comparison of Wavelengths with the Interferometer	305
14.14	Study of Hyperfine Structure and of Line Shape	308
14.15	Other Interference Spectroscopes	310
14.16	Channeled Spectra. Interference Filter	311
15	**Fraunhofer Diffraction by a Single Opening**	**315**
15.1	Fresnel and Fraunhofer Diffraction	315
15.2	Diffraction by a Single Slit	316
15.3	Further Investigation of the Single-Slit Diffraction Pattern	319
15.4	Graphical Treatment of Amplitudes. The Vibration Curve	322
15.5	Rectangular Aperture	324
15.6	Resolving Power with a Rectangular Aperture	325
15.7	Chromatic Resolving Power of a Prism	327
15.8	Circular Aperture	329
15.9	Resolving Power of a Telescope	330
15.10	Resolving Power of a Microscope	332
15.11	Diffraction Patterns with Sound and Microwaves	334
16	**The Double Slit**	**338**
16.1	Qualitative Aspects of the Pattern	338
16.2	Derivation of the Equation for the Intensity	339
16.3	Comparison of the Single-Slit and Double-Slit Patterns	341
16.4	Distinction between Interference and Diffraction	341
16.5	Position of the Maxima and Minima. Missing Orders	342
16.6	Vibration Curve	346
16.7	Effect of Finite Width of Source Slit	347
16.8	Michelson's Stellar Interferometer	349
16.9	Correlation Interferometer	351
16.10	Wide-Angle Interference	352
17	**The Diffraction Grating**	**355**
17.1	Effect of Increasing the Number of Slits	355
17.2	Intensity Distribution from an Ideal Grating	357
17.3	Principal Maxima	358
17.4	Minima and Secondary Maxima	358
17.5	Formation of Spectra by a Grating	359
17.6	Dispersion	362
17.7	Overlapping of Orders	362
17.8	Width of the Principal Maxima	363
17.9	Resolving Power	364
17.10	Vibration Curve	365
17.11	Production of Ruled Gratings	368
17.12	Ghosts	370

17.13	Control of the Intensity Distribution among Orders	370
17.14	Measurement of Wavelength with the Grating	373
17.15	Concave Grating	373
17.16	Grating Spectrographs	374
18	**Fresnel Diffraction**	**378**
18.1	Shadows	378
18.2	Fresnel's Half-Period Zones	380
18.3	Diffraction by a Circular Aperture	383
18.4	Diffraction by a Circular Obstacle	384
18.5	Zone Plate	385
18.6	Vibration Curve for Circular Division of the Wave Front	386
18.7	Apertures and Obstacles with Straight Edges	388
18.8	Strip Division of the Wave Front	389
18.9	Vibration Curve for Strip Division. Cornu's Spiral	389
18.10	Fresnel's Integrals	390
18.11	The Straight Edge	393
18.12	Rectilinear Propagation of Light	395
18.13	Single Slit	397
18.14	Use of Fresnel's Integrals in Solving Diffraction Problems	399
18.15	Diffraction by an Opaque Strip	400
19	**The Speed of Light**	**403**
19.1	Römer's Method	403
19.2	Bradley's Method. The Aberration of Light	405
19.3	Michelson's Experiments	406
19.4	Measurements in a Vacuum	408
19.5	Kerr-Cell Method	408
19.6	Speed of Radio Waves	410
19.7	Ratio of the Electrical Units	411
19.8	The Speed of Light in Stationary Matter	411
19.9	Speed of Light in Moving Matter	412
19.10	Fresnel's Dragging Coefficient	413
19.11	Airy's Experiment	414
19.12	Effect of Motion of the Observer	414
19.13	The Michelson-Morley Experiment	416
19.14	Principle of Relativity	418
19.15	The Three First-Order Relativity Effects	419
20	**The Electromagnetic Character of Light**	**423**
20.1	Transverse Nature of Light Vibrations	424
20.2	Maxwell's Equations for a Vacuum	424
20.3	Displacement Current	425
20.4	The Equations for Plane Electromagnetic Waves	427
20.5	Pictorial Representation of an Electromagnetic Wave	428
20.6	Light Vector in an Electromagnetic Wave	429

20.7	Energy and Intensity of the Electromagnetic Wave	429
20.8	Radiation from an Accelerated Charge	430
20.9	Radiation From a Charge in Periodic Motion	432
20.10	Hertz's Verification of the Existence of Electromagnetic Waves	432
20.11	Speed of Electromagnetic Waves in Free Space	434
20.12	Čerenkov Radiation	434
21	**Sources of Light and Their Spectra**	**438**
21.1	Classification of Sources	438
21.2	Solids at High Temperature	439
21.3	Metallic Arcs	439
21.4	Bunsen Flame	442
21.5	Spark	442
21.6	Vacuum Tube	443
21.7	Classification of Spectra	445
21.8	Emittance and Absorptance	445
21.9	Continuous Spectra	447
21.10	Line Spectra	450
21.11	Series of Spectral Lines	452
21.12	Band Spectra	458
22	**Absorption and Scattering**	**457**
22.1	General and Selective Absorption	457
22.2	Distinction between Absorption and Scattering	458
22.3	Absorption by Solids and Liquids	459
22.4	Absorption by Gases	461
22.5	Resonance and Fluorescence of Gases	461
22.6	Fluorescence of Solids and Liquids	464
22.7	Selective Reflection. Residual Rays	464
22.8	Theory of the Connection between Absorption and Reflection	465
22.9	Scattering by Small Particles	466
22.10	Molecular Scattering	468
22.11	Raman Effect	469
22.12	Theory of Scattering	470
22.13	Scattering and Refractive Index	471
23	**Dispersion**	**474**
23.1	Dispersion of a Prism	474
23.2	Normal Dispersion	475
23.3	Cauchy's Equation	479
23.4	Anomalous Dispersion	479
23.5	Sellmeier's Equation	482
23.6	Effect of Absorption on Dispersion	485
23.7	Wave and Group Velocity in the Medium	487
23.8	The Complete Dispersion Curve of a Substance	488
23.9	The Electromagnetic Equations for Transparent Media	489

23.10	Theory of Dispersion	491
23.11	Nature of the Vibrating Particles and Frictional Forces	494
24	**The Polarization of Light**	**497**
24.1	Polarization by Reflection	498
24.2	Representation of the Vibrations in Light	499
24.3	Polarizing Angle and Brewster's Law	500
24.4	Polarization by a Pile of Plates	501
24.5	Law of Malus	503
24.6	Polarization by Dichroic Crystals	504
24.7	Double Refraction	505
24.8	Optic Axis	507
24.9	Principal Sections and Principal Planes	507
24.10	Polarization by Double Refraction	508
24.11	Nicol Prism	510
24.12	Parallel and Crossed Polarizers	511
24.13	Refraction by Calcite Prisms	511
24.14	Rochon and Wollaston Prisms	513
24.15	Scattering of Light and the Blue Sky	514
24.16	The Red Sunset	515
24.17	Polarization by Scattering	516
24.18	The Optical Properties of Gemstones	518
25	**Reflection**	**523**
25.1	Reflection from Dielectrics	523
25.2	Intensities of the Transmitted Light	526
25.3	Internal Reflection	527
25.4	Phase Changes on Reflection	527
25.5	Reflection of Plane-polarized Light from Dielectrics	529
25.6	Elliptically Polarized Light by Internal Reflection	531
25.7	Penetration into the Rare Medium	533
25.8	Metallic Reflection	534
25.9	Optical Constants of Metals	536
25.10	Description of the Light Reflected from Metals	538
25.11	Measurement of the Principal Angle of Incidence and Principal Azimuth	540
25.12	Wiener's Experiments	541
26	**Double Refraction**	**544**
26.1	Wave Surfaces for Uniaxial Crystals	544
26.2	Propagation of Plane Waves in Uniaxial Crystals	546
26.3	Plane Waves at Oblique Incidence	549
26.4	Direction of the Vibrations	550
26.5	Indices of Refraction for Uniaxial Crystals	551
26.6	Wave Surfaces in Biaxial Crystals	553
26.7	Internal Conical Refraction	556

26.8	External Conical Refraction	557
26.9	Theory of Double Refraction	559
27	**Interference of Polarized Light**	**564**
27.1	Elliptically and Circularly Polarized Light	564
27.2	Quarter- and Half-Wave Plates	567
27.3	Crystal Plates between Crossed Polarizers	568
27.4	Babinet Compensator	569
27.5	Analysis of Polarized Light	571
27.6	Interference with White Light	572
27.7	Polarizing Monochromatic Filter	575
27.8	Applications of Interference in Parallel Light	576
27.9	Interference in Highly Convergent Light	576
28	**Optical Activity and Modern Wave Optics**	**581**
28.1	Rotation of the Plane of Polarization	581
28.2	Rotary Dispersion	582
28.3	Fresnel's Explanation of Rotation	584
28.4	Double Refraction in Optically Active Crystals	586
28.5	Shape of the Wave Surfaces in Quartz	588
28.6	Fresnel's Multiple Prism	589
28.7	Cornu Prism	590
28.8	Vibration Forms and Intensities in Active Crystals	591
28.9	Theory of Optical Activity	593
28.10	Rotation in Liquids	594
28.11	Modern Wave Optics	596
28.12	Spatial Filtering	597
28.13	Phase-Contrast Microscope	602
28.14	Schlieren Optics	604
Part Three	**Quantum Optics**	
29	**Light Quanta and Their Origin**	**611**
29.1	The Bohr Atom	612
29.2	Energy Levels	616
29.3	Bohr-Stoner Scheme for Building Up Atoms	617
29.4	Elliptical Orbits, or Penetrating Orbitals	619
29.5	Wave Mechanics	622
29.6	The Spectrum of Sodium	625
29.7	Resonance Radiation	626
29.8	Metastable States	629
29.9	Optical Pumping	630
30	**Lasers**	**632**
30.1	Stimulated Emission	633
30.2	Laser Design	634

此为试读,需要完整PDF请访问: www.ertongbook.com