

The background of the book cover features a close-up, artistic photograph of a lens or optical component. The lens is curved and reflects light, with a bright, multi-colored spot (likely a reflection of a light source) visible on its surface. The overall color palette is dominated by deep blues, purples, and greens, creating a high-tech, scientific atmosphere. The text is overlaid on this background.

SPIE
PRESS

Modern Optical Engineering

FOURTH EDITION

Warren J. Smith

Contents

Preface xi

Chapter 1. Optics Overview	1
1.1 The Electromagnetic Spectrum	1
1.2 Light Wave Propagation	3
1.3 Snell's Law of Refraction	5
1.4 The Action of Simple Lenses and Prisms on Wave Fronts	8
1.5 Interference and Diffraction	11
1.6 The Photoelectric Effect	16
Bibliography	17
Exercises	18
 Chapter 2. Gaussian Optics: The Cardinal Points	 21
2.1 Introduction	21
2.2 Cardinal Points of an Optical System	22
2.3 Image Position and Size	24
2.4 A Collection of Imagery Equations	30
2.5 Optical Systems <i>Not</i> Immersed in Air	31
Bibliography	32
Exercises	32
 Chapter 3. Paraxial Optics and Calculations	 35
3.1 Refraction of a Light Ray at a Single Surface	35
3.2 The Paraxial Region	37
3.3 Paraxial Raytracing through Several Surfaces	39
3.4 Calculation of the Focal Points and Principal Points	44
3.5 The "Thin Lens"	47
3.6 Mirrors	49
Bibliography	51
Exercises	51

Chapter 4. Optical System Considerations	53
4.1 Systems of Separated Components	53
4.2 The Optical Invariant	58
4.3 Matrix Optics	63
4.4 The y - y bar Diagram	64
4.5 The Scheimpflug Condition	65
4.6 Summary of Sign Conventions	67
Bibliography	67
Exercises	68
Chapter 5. The Primary Aberrations	71
5.1 Introduction	71
5.2 The Aberration Polynomial and the Seidel Aberrations	72
5.3 Chromatic Aberrations	83
5.4 The Effect of Lens Shape and Stop Position on the Aberrations	84
5.5 Aberration Variation with Aperture and Field	88
5.6 Optical Path Difference (Wave Front Aberration)	90
5.7 Aberration Correction and Residuals	91
5.8 Ray Intercept Curves and the “Orders” of Aberrations	94
5.9 The Relationships between Longitudinal Aberration, Transverse Aberration, Wave-Front Aberration (OPD), and Angular Aberration	99
Bibliography	102
Exercises	102
Chapter 6. Third-Order Aberration Theory and Calculation	105
6.1 Introduction	105
6.2 Paraxial Raytracing	107
6.3 Third-Order Aberrations: Surface Contributions	108
6.4 Third-Order Aberrations: Thin Lenses; Stop Shift Equations	113
6.5 Sample Calculations	117
Bibliography	122
Chapter 7. Prism and Mirror Systems	123
7.1 Introduction	123
7.2 Dispersing Prisms	123
7.3 The “Thin” Prism	125
7.4 Minimum Deviation	126
7.5 The Achromatic Prism and the Direct Vision Prism	126
7.6 Total Internal Reflection	128
7.7 Reflection from a Plane Surface	129
7.8 Plane Parallel Plates	132
7.9 The Right-Angle Prism	136
7.10 The Roof Prism	139
7.11 Erecting Prism Systems	141
7.12 Inversion Prisms	144
7.13 The Penta Prism	145

7.14 Rhomboids and Beamsplitters	146
7.15 Plane Mirrors	149
7.16 The Design of Prism and Reflector Systems	149
7.17 Analysis of Fabrication Errors	154
Bibliography	155
Chapter 8. Characteristics of the Human Eye	157
8.1 Introduction	157
8.2 The Structure of the Eye	158
8.3 Characteristics of the Eye	160
8.4 Defects of the Eye	168
Bibliography	170
Experiments	171
Exercises	172
Chapter 9. Stops, Apertures, Pupils and Diffraction	175
9.1 Introduction	175
9.2 The Aperture Stop and Pupils	176
9.3 The Field Stop	177
9.4 Vignetting	177
9.5 Glare Stops, Cold Stops, and Baffles	179
9.6 The Telecentric Stop	182
9.7 Apertures and Image Illumination— f -Number and Cosine-Fourth	183
9.8 Depth of Focus	186
9.9 Diffraction Effects of Apertures	188
9.10 Resolution of Optical Systems	192
9.11 Diffraction of a Gaussian (Laser) Beam	195
9.12 The Fourier Transform Lens and Spatial Filtering	199
Bibliography	200
Exercises	201
Chapter 10. Optical Materials	205
10.1 Reflection, Absorption, Dispersion	205
10.2 Optical Glass	210
10.3 Special Glasses	216
10.4 Crystalline Materials	219
10.5 Plastic Optical Materials	221
10.6 Absorption Filters	224
10.7 Diffusing Materials and Projection Screens	227
10.8 Polarizing Materials	230
10.9 Cements and Liquids	232
Bibliography	233
Exercises	234
Chapter 11. Optical Coatings	237
11.1 Dielectric Reflection and Interference Filters	237
11.2 Reflectors	247

11.3	Reticles	250
	Bibliography	251
	Exercises	252
Chapter 12.	Principles of Radiometry and Photometry	253
12.1	Introduction	253
12.2	The Inverse Square Law; Intensity	254
12.3	Radiance and Lambert's Law	255
12.4	Radiation into a Hemisphere	256
12.5	Irradiance Produced by a Diffuse Source	257
12.6	The Radiometry of Images	259
12.7	Spectral Radiometry	263
12.8	Blackbody Radiation	264
12.9	Photometry	270
12.10	Illumination Devices	277
	Bibliography	282
	Exercises	283
Chapter 13.	Optical System Layout	287
13.1	Telescopes, Afocal Systems	287
13.2	Field Lenses and Relay Systems	291
13.3	Exit Pupils, the Eye, and Resolution	293
13.4	The Simple Microscope or Magnifier	303
13.5	The Compound Microscope	305
13.6	Rangefinders	307
13.7	Radiometer and Detector Optics	311
13.8	Fiber Optics	318
13.9	Anamorphic Systems	323
13.10	Variable-Power (Zoom) Systems	328
13.11	The Diffractive Surface	333
	Bibliography	334
	Exercises	334
Chapter 14.	Case Studies in System Layout	339
14.1	Introduction	339
14.2	Telephoto Lens	340
14.3	Retrofocus Lens	341
14.4	Relay System	342
14.5	Aperture Stop for Relay System of Sec. 14.4	343
14.6	Short Range Telescope	344
14.7	Field Lens for Sec. 14.6	347
14.8	Raytrace of Sec. 14.7	348
14.9	125 Power Microscope	349
14.10	Brueke 125× Magnifier	350
14.11	A 4× Mechanically Compensated Zoom Lens	351
14.12	Doing System Layout by Computer	356
14.13	An Athermalized Mid-IR System with an External Cold Stop	357

Chapter 15. Wave-Front Aberrations and MTF	365
15.1 Introduction	365
15.2 Optical Path Difference: Focus Shift	366
15.3 Optical Path Difference: Spherical Aberration	367
15.4 Aberration Tolerances	373
15.5 Image Energy Distribution (Geometric)	379
15.6 Spread Functions—Point and Line	380
15.7 Geometric Spot Size Due to Spherical Aberration	381
15.8 The Modulation Transfer Function	385
15.9 Square-Wave vs. Sine-Wave Targets	391
15.10 Special Modulation Transfer Functions: Diffraction-Limited Systems	392
15.11 Radial Energy Distribution	401
15.12 Point Spread Functions for the Primary Aberrations	402
Bibliography	407
Exercises	408
Chapter 16. The Basics of Lens Design	409
16.1 Introduction	409
16.2 The Simple Meniscus Camera Lens	411
16.3 The Symmetrical Principle	417
16.4 Achromatic Telescope Objectives (Thin-Lens Theory)	417
16.5 Achromatic Telescope Objectives (Design Forms)	421
16.6 The Diffractive Surface in Lens Design	430
16.7 The Cooke Triplet Anastigmat: Third-Order Theory	435
16.8 Automatic Design by Electronic Computer	446
16.9 Practical Considerations	451
Bibliography	453
Exercises	454
Chapter 17. Lens Design for Eyepieces, Microscopes, Cameras, etc.	457
17.1 Telescope Systems and Eyepieces	457
17.2 Microscope Objectives	466
17.3 Photographic Objectives	473
17.4 Condenser Systems	494
17.5 Aberration Characteristics of Simple Lenses	498
Bibliography	501
Exercises	501
Chapter 18. Design of Mirror and Catadioptric Systems	503
18.1 Reflecting Systems	503
18.2 The Spherical Mirror	503
18.3 The Paraboloid Reflector	506
18.4 The Ellipsoid and Hyperboloid	507
18.5 Equations for Two-Mirror Systems	508
18.6 Conic Section through the Origin	513
18.7 The Schmidt System	515

18.8 The Mangin Mirror	517
18.9 The Bouwers (Maksutov) System	519
18.10 The Rapid Estimation of Blur Sizes for Simple Optical Systems	522
Bibliography	526
Exercises	527
Chapter 19. Selected Lens Designs, Analyzed and Annotated	529
19.1 Introduction	529
19.2 Lens Data Tables	529
19.3 Raytrace Figures	530
19.4 A Note Re the Modulation Transfer Function	531
19.5 Index to the Lenses	532
19.6 The Lenses	534
Bibliography	597
Chapter 20. The Practice of Optical Engineering	599
20.1 Optical Manufacture	599
20.2 Optical Specifications and Tolerances	610
20.3 Optical Mounting Techniques	628
20.4 Optical Laboratory Practice	633
20.5 Tolerance Budget Example	652
Bibliography	656
Chapter 21. Getting the Most Out of “Stock” Lenses	659
21.1 Introduction	659
21.2 Stock Lenses	659
21.3 Some Simple Measurements	661
21.4 System Mock-up and Test	665
21.5 Aberration Considerations	668
21.6 How to Use a Singlet (Single Element)	671
21.7 How to Use a Cemented Doublet	675
21.8 Combinations of Stock Lenses	676
21.9 Sources	684
Appendix A. Raytracing and Aberration Calculation	687
Appendix B. Some Standard Dimensions	707
Glossary	709
Index	733