

Contents

1	What Is Light?	1
1.1	What Did Einstein Have to Say About Blue and Red Light?	1
1.2	Light as a Wave	3
1.2.1	The Double Slit Experiment.	4
1.2.2	A Freehand Interference Experiment.	4
1.2.3	Diffraction	5
1.3	Light as an Electromagnetic Phenomenon	6
1.4	Digression: Are Wave and Particle (Photon) Concepts Compatible?	8
1.5	Light and Color.	9
1.6	Polarization.	13
1.7	Laser Light	16
1.8	Digression: The Concept of Coherence	18
1.8.1	Coherent Light in the Sense of Quantum Optics	19
2	The Interaction Between Light and Matter	21
2.1	Phenomenology	21
2.2	Fundamental Physical Processes	21
2.3	Transparency.	23
2.4	Refraction	26
2.4.1	The Law of Refraction	26
2.4.2	Dispersion.	27
2.5	Specular Reflection.	28
2.6	Diffuse Reflection at Surfaces	30
2.7	Light Scattering in Media.	30
2.8	Absorption	34
2.9	Fluorescence.	35
2.10	Diffraction	38
3	Light Sources	41
3.1	Thermal Light.	41
3.1.1	Luminous Efficiency	43
3.2	Fluorescent Tubes.	43
3.3	Light Emitting Diodes (LEDs)	44
3.4	Lasers	46
3.4.1	How Laser Light Is Created: The Principle	46
3.4.2	Laser Types.	49

3.4.3	Semiconductor Laser	49
3.4.4	The Excimer Laser	50
3.4.5	Digression: Technical History of Lasers	50
3.5	Superluminescent Diodes (SLED)	50
4	Examinations with Light	53
4.1	Methods on the Basis of Classical Optics	53
4.1.1	The Ophthalmoscope (Direct Ophthalmoscopy)	53
4.1.2	Indirect Ophthalmoscopy	56
4.1.3	The Slit Lamp	57
4.1.4	Contact Lenses	59
4.1.5	Funduscopy with the Slit Lamp	60
4.1.6	The Operating Microscope	60
4.1.7	Retinoscopy (Skiascopy, Shadow Test)	61
4.1.8	Refractometry	63
4.1.9	Keratometry and Corneal Topography	64
4.1.10	Pachymetry	67
4.1.11	Fundus Photography	67
4.1.12	Confocal Scanning Laser Ophthalmoscope	67
4.1.13	Perimetry	69
4.2	Interferometric Methods	72
4.2.1	Interferometry: The Principle	73
4.2.2	For a Start: Interferometry with Monochromatic Light	74
4.2.3	White Light Interferometry	75
4.2.4	Optical Low Coherence Reflectometry (OLCR)	76
4.2.5	Time Domain Optical Coherence Tomography (TD-OCT)	76
4.2.6	Spectral Domain Optical Coherence Tomography (SD-OCT)	78
4.2.7	Laser Speckles	78
4.3	The Laser Doppler Principle	79
5	Ultrasound Diagnostics	83
5.1	Sound and Ultrasound	83
5.1.1	Frequency, Wavelength, Resolution, Attenuation	85
5.1.2	Reflection, Refraction, Scattering, and Diffraction of Ultrasound	85
5.1.3	Digression: Impedance	87
5.1.4	Sound Probe and Receiver	88
5.2	Sonography	89
5.2.1	A-Scan	89
5.2.2	B-Scan	90
5.2.3	Ultrasound Biomicroscopy (UBM)	91
5.3	Doppler Sonography	91
5.3.1	Color Duplex Sonography	92
5.3.2	Spectral Doppler Ultrasound	92
5.3.3	Indices	93
5.4	Ultrasound in Therapy	94

6	Further Imaging Procedures	95
6.1	Analog Radiography	95
6.2	Digital Radiography	96
6.3	Computed Tomography (CT)	97
6.4	Magnetic Resonance Tomography (MRT or MRI)	99
6.4.1	Nuclear Spin Resonance: The Phenomenon	99
6.4.2	Nuclear Spin Resonance: A Brief Explanation	100
6.4.3	From Nuclear Spin Resonance to MRI: Location Coding	102
6.4.4	Relaxation Times and Associated Measurement Processes	102
6.4.5	Examples of Clinical Applications of MRI	103
7	Interventions with Laser Light	105
7.1	Photocoagulation	107
7.1.1	Biological Effects of Heating	109
7.1.2	Heating and Heat Diffusion	110
7.2	Photodisruption	111
7.3	Photoablation	113
7.4	Cutting with the Femtosecond Laser	114
8	Some History of Chemistry	117
8.1	First Steps Toward Modern Chemistry	117
8.2	The Birth of Elements	119
9	Oxygen	121
9.1	The Oxygen Atom	121
9.2	Oxygen and Energy Production	122
9.3	Biochemical Reactions of Oxygen	123
9.4	Oxygen Delivery to Biological Tissues	127
9.5	Oxygen Deficiency in Tissues	128
9.6	Oxygen in the Eye	130
9.7	Consequences of Hypoxia in the Eye	131
10	Water	135
10.1	What Is Water?	135
10.2	Water in the Universe	136
10.3	Water on Earth	136
10.4	Water in Biology	137
10.5	Water in Medicine	137
10.6	Water in the Eye	137
11	Carbon Dioxide (CO₂)	139
11.1	What Is Carbon Dioxide?	139
11.2	Transport of Carbon Dioxide	139
11.3	Carbon Dioxide in Medicine	140
11.4	Carbon Dioxide in the Eye	140
12	Nitric Oxide	143
12.1	Nitric Oxide Molecule	143
12.2	Nitric Oxide in History	143
12.3	Nitric Oxide in Biology	144

12.4	Nitric Oxide in Medicine	146
12.5	Nitric Oxide in the Eye.....	147
12.5.1	NO and Aqueous Humor Dynamics.....	147
12.5.2	NO and Ocular Blood Flow	149
12.5.3	NO in Eye Disease	150
12.5.4	NO in Therapy	153
13	Redox Reactions.....	155
13.1	Redox Chemistry and Terminology	155
13.2	Production of ROS	156
13.3	Oxidative Stress	157
13.4	Oxidative Stress in the Eye.....	158
13.5	Antioxidants	160
13.6	Further Antioxidants in Nutrition.....	162
14	DNA.....	169
14.1	DNA as the Hard Disk of the Cell	169
14.2	Discovery of DNA	169
14.3	Structure and Function of DNA	171
14.4	The Role of DNA Mutation	173
14.5	Acquired DNA Damage and Its Repair	175
15	RNA.....	179
15.1	Discovery of RNA	180
15.2	Structure and Function of RNA	180
15.2.1	Messenger RNA	180
15.2.2	Transfer RNA	180
15.2.3	Ribosomal RNA	180
15.3	RNA and Cell Function	181
15.4	Diagnostics Based on RNA	183
15.5	Therapies Based on RNA	184
16	Proteins.....	187
16.1	Discovery of Proteins	187
16.2	Structure of Proteins.....	188
16.3	Information Content of a Protein	191
16.4	Roles of Proteins.....	191
16.5	Roles of Proteins in the Eye.....	193
16.5.1	Proteins in the Cornea	193
16.5.2	Proteins in the Lens	194
16.5.3	Proteins in the Vitreous	194
16.5.4	Proteins in the Retina	195
16.6	Proteins in the Vascular System	198
16.6.1	Endothelial Derived Vasoactive Factors (EDVFs) ..	198
16.6.2	Endothelin.....	199
16.7	Enzymes	202
16.8	Antibodies.....	206

17 Lipids 209

17.1 Tear Film..... 209

17.2 Lipids in the Retina 212

18 Matter: Using Water as an Example 217

18.1 The Isolated Water Molecule 217

18.2 The H-Bond in Ice and Water..... 218

18.3 Heat and Temperature..... 219

18.4 Solubility of Gases: Partial Pressure 220

18.5 Surface Tension 222

18.6 Silicone Oil–Water Interface 223

18.7 Viscosity..... 224

19 If You Are Interested in More..... 229

19.1 Ray Optics or Wave Optics?..... 229

19.2 Simple Lenses and Achromats 230

19.3 Adaptive Optics 232

19.3.1 The Concept of the Wavefront 233

19.3.2 Measuring a Wavefront..... 233

19.4 Abbe’s Limit of Resolution and the STED Microscope. . . 235

19.5 Fourier Analysis 235

19.5.1 Fourier Decomposition of Periodic Functions . . . 237

19.5.2 Fourier Decomposition
of Non-periodic Functions 237

19.5.3 Applications 238

20 Appendix: Units and Constants 239

20.1 Some Physical Units..... 239

20.1.1 Length..... 239

20.1.2 Frequency..... 239

20.1.3 Mass 239

20.1.4 Force 239

20.1.5 Energy..... 239

20.1.6 Power 240

20.1.7 Pressure..... 240

20.1.8 Temperature 240

20.1.9 Viscosity..... 240

20.1.10 Surface Tension, Interfacial Tension 241

20.1.11 Room Angle 241

20.2 Photometric Units..... 241

20.2.1 Luminous Flux 241

20.2.2 Illuminance..... 241

20.2.3 Luminance 242

20.3 Some Physical Constants 243

Index 245