

Contents

<i>Preface</i>	<i>page xi</i>
<i>Acknowledgements</i>	xv
1 Historical introduction	1
1.1 Early discoveries in polarization	2
1.2 A mathematical formulation of polarization	4
1.3 Discovery of the Zeeman effect	5
1.4 Radiative transfer for polarized light	6
2 A review of some basic concepts	9
2.1 Light as an electromagnetic wave	10
2.2 The monochromatic, time-harmonic plane wave	12
2.3 The polarization tensor	13
2.4 The Stokes parameters of a monochromatic, time-harmonic plane wave	16
3 The polarization properties of quasi-monochromatic light	19
3.1 Polychromatic light as a statistical superposition of monochromatic light	19
3.2 The quasi-monochromatic plane wave	21
3.3 The polarization tensor and the Stokes parameters of a quasi-monochromatic plane wave	22
3.4 Degree of polarization and the Poincaré sphere	24
3.5 Measuring the polarization state of quasi-monochromatic light	29
3.6 A further perspective on polarization properties	33
4 Linear optical systems acting on polarized light	36
4.1 Propagation of light through anisotropic media	36
4.1.1 Measurable effects of anisotropy	40
4.2 The extraordinary index of refraction and the energy propagation direction	42

4.3	Some notational conventions	44
4.4	Transforming the polarization state of light	45
4.5	The Mueller matrix and some of its properties	45
4.6	Block components of (solar) polarimeters	49
4.6.1	Rotation of the reference frame	49
4.6.2	The linear analyzer–polarizer	50
4.6.3	The partial linear polarizer	53
4.6.4	The linear retarder	53
4.6.5	The Mueller matrix of an optical train	54
4.7	Spatial and temporal modulation	55
4.7.1	Spatial modulation	56
4.7.2	Temporal modulation	61
5	Solar polarimetry	64
5.1	Environmental polarization	65
5.1.1	Seeing-induced polarization	66
5.1.2	Instrumental polarization	70
5.2	The polarization analysis system	74
5.2.1	The optimum modulation matrix	76
5.2.2	The optimum demodulation matrix	78
5.3	Some solar Stokes polarimeters	79
5.3.1	ZIMPOL	79
5.3.2	ASP	81
5.3.3	TIP and LPSP	82
5.4	A practical discussion of polarimetric efficiencies	83
6	Absorption and dispersion	87
6.1	Light propagation through low-density, weakly conducting media	88
6.2	Absorption and dispersion profiles	91
6.3	A correction from quantum mechanics	95
6.4	Accounting for thermal motions in the medium	97
6.5	Spectral line absorption in moving media	100
7	The radiative transfer equation	102
7.1	A little geometry	103
7.2	Variations of the coherency matrix along the ray path	105
7.3	Variation of the Stokes parameters along the ray path	106
7.4	Some properties of the propagation matrix	109
7.5	Emission processes	112
7.6	The RTE for spectral line formation	115

7.7	Radiative transfer through isotropic media	116
7.8	Propagation along the optical axis and in a perpendicular direction	117
8	The RTE in the presence of a magnetic field	121
8.1	The Lorentz model of the electron	121
8.1.1	Symmetry properties of the propagation matrix elements	126
8.2	<i>LS</i> coupling	127
8.3	The Zeeman effect	129
8.3.1	Allowed atomic transitions	131
8.3.2	The Zeeman pattern	132
8.3.3	Relative intensities of the Zeeman components	136
8.4	The elements of the propagation matrix	137
8.4.1	The effective Zeeman triplet	139
8.5	The RTE in the presence of a magnetic field	146
9	Solving the radiative transfer equation	149
9.1	The model atmosphere	149
9.2	The formal solution	150
9.2.1	Symmetry properties of the solution	150
9.2.2	The evolution operator	152
9.2.3	Solving the inhomogeneous equation	152
9.2.4	The action of macroturbulence on the Stokes profiles	153
9.3	Actual (numerical) solutions of the RTE	154
9.4	Simple solutions of the RTE	158
9.4.1	The Milne–Eddington atmosphere	159
9.4.2	Longitudinal magnetic field	160
9.5	Simple diagnostics	162
10	Stokes spectrum diagnostics	165
10.1	Probing the medium by scanning spectral lines	166
10.1.1	The isotropic case	166
10.1.2	The anisotropic case	170
10.2	Height of formation of spectral lines and the fundamental ill-definition of the CFs	173
10.2.1	Alternative CF definitions	175
10.3	The sensitivities of Stokes profiles	175
10.3.1	Linearization of the RTE and response functions	176
10.3.2	Properties of response functions	185

10.4	A theoretical description of measurement	189
10.4.1	Generalized response functions	191
10.4.2	An example	192
10.4.3	Understanding measurements theoretically	194
11	Inversion of the RTE	199
11.1	The χ^2 merit function	201
11.1.1	Derivatives of the χ^2 merit function	202
11.2	The Marquardt method	204
11.2.1	Error calculation	206
11.2.2	Problems in practice	208
11.3	Parameters at the nodes and equivalent response functions	209
11.4	Less significant parameters and singular value decomposition	212
11.4.1	Modified singular value decomposition	214
11.5	An example	216
11.6	Current and future inversion techniques	218
	<i>Index</i>	220