CONTENTS

I. RADIATIVE EQUILIBRIUM OF THE OUTER LAYERS . 1
1. Introduction 1
2. The transfer of radiation 1
3. Eddington's treatment. The first approximation . . . 4
3.1. The darkening of the limb 5
3.2. The equivalent mean intensity 6
4. Some radiation laws 7
4.1. The effective temperature of radiation 7
4.2. The effective temperature of the Sun 8
5. Eddington's second approximation 9
5.1. The boundary condition 9
5.2. Integral forms for $I(\tau, \theta)$ involving the source function . . 10
5.21. Physical interpretation of the integrals for $I(\tau, \theta)$ . . 11
5.3. J, H, and K in the second approximation . . . 12
5.31. The amended second approximation . . . 13
5.32. Limb darkening 14

II. OTHER APPROXIMATE METHODS OF SOLVING THE EQUATION OF TRANSFER 16
1. Schwarzschild's approximate solution 16
1.1. Equations for the mean intensities 16
1.2. Limb darkening and the net flux 17
2. Chandrasekhar's approximations 18
2.1. Equations for the intensities, and the general solution . . 20
2.2. The source function in the nth approximation . . . 22
2.21. The intensity in any direction 23
2.3. Calculation of the integration constants 25
2.4. Limb darkening in the nth approximation . . . 25
2.5. The first approximation and higher approximations . . 27

III. THE INTEGRAL EQUATIONS OF RADIATIVE EQUILIBRIUM: EXACT SOLUTIONS 30
1. The integral equations of Schwarzschild and Milne . . . 30
1.1. The asymptotic behaviour of $J(\tau)$ 31
1.2. Hopf's solution by iteration 31
2. An integral equation for $q(\tau)$ 34
2.1. The Liouville–Neumann solution 35
2.2. The Hopf–Bronstein boundary value $q(0) = 1/\sqrt{3}$ . . 35
3. Exact solutions for the emergent intensity and the source function . 37
3.1. Significance of the Laplace transform 37
3.2. An integral equation for the Laplace transform of the source function 38

3.3. Limit forms for $q(0)$ and $q(\infty)$ 39
3.4. The Wiener–Hopf solution 40
3.41. Determination of $q(0)$ and $q(\infty)$ 43
3.42. The emergent intensity $I(0, \mu)$ 44
3.5. Mark's exact solution for $q(\tau)$ 45
4. A comparison of solutions 48

IV. THE CONTINUOUS SPECTRUM 52
1. Monochromatic radiative transfer with the absorption coefficient a function of frequency 52
1.1. Mean coefficients of absorption—the straight mean and Rosseland's mean 54
2. A microscopic analysis of the hypothesis of local thermodynamic equilibrium 57
3. Physical nature of the continuous absorption coefficient . . 60
3.1. The negative hydrogen ion 62
3.2. The mass coefficient of absorption 66

V. THE VARIATION OF ABSORPTION COEFFICIENT WITH WAVE-LENGTH IN THE SOLAR ATMOSPHERE . . 70
1. Limb darkening in monochromatic light 70
1.1. Milne's calculation of the darkening of the limb in a grey atmosphere 71
1.2. The blanketing effect 71
1.21. Milne's theory 72
1.22. An alternative theory 73
2. Connexion between limb darkening and the variation of absorption coefficient with wave-length 75
2.1. Lundblad's analysis 77
3. Comparison between theory and observation 78
3.1. Relative absorption coefficients $k_\lambda/\bar{k}$ 78
3.11. Determination from the energy curve 78
3.12. Determination from limb darkening 79
3.13. Comparison with the coefficient of the negative hydrogen ion 81
3.14. A check on the relative coefficients 84
3.2. The temperature distribution 85
3.3. Summary 90

VI. THE PHYSICAL NATURE OF LINE ABSORPTION . . 91
1. Introduction 91
2. The classical oscillator 91
2.1. Absorption 92
2.2. Emission 94
3. Collision damping 97
3.1. Impact broadening 97
3.2. Phase collisions 99

4. The quantum atom 106
4.1. Transition coefficients 106
4.2. Oscillator strength 109
4.3. Broadened states 110
4.4. Stark effect 115
5. Excitation by collisions 116
6. Doppler effect 122

VII. THE COHERENT FORMATION OF ABSORPTION LINES . 126
1. Introduction 126
2. The equation of line formation by coherent scattering . . 127
3. Eddington's solution for η constant 130
4. Residual intensity in an absorption line 131
4.1. The mean contour. Central intensity 131
4.2. Variation from centre to limb 133
4.3. Second approximation to the mean contour . . . 135
5. A comparison of solutions. Errors of the approximate solutions . 136
6. Line formation when η varies with depth 139
6.1. The dependence of η on physical conditions . . . 139
6.2. Soluble cases for empirical forms 140
6.3. The treatment of arbitrary variations 141
6.31. Strömgren's solution for the emergent flux in an absorption line 142
6.32. Formulae for numerical calculation of the mean contour . 145

VIII. THE FORMATION OF ABSORPTION LINES BY NON-COHERENT PROCESSES 151
1. The nature of non-coherent scattering 151
2. Interlocking without redistribution 152
2.1. Lines with a common upper state 152
2.2. Rosseland's theorem of cycles 157
2.3. The effect of electron capture 161
3. Redistribution in frequency 164
3.1. Effect in a single atom 164
3.2. Effects due to other atoms 168
3.3. Influence of the Doppler effect 170
4. Approximate solution of the equations 173

IX. THE PHOTOSPHERE 176
1. Introduction 176
2. Mechanical equilibrium of the photosphere 176
2.1. Radiation pressure 177
2.2. Hydrostatic equilibrium 178
3. The structure of the outer layers 179
3.1. The method of model atmospheres 180
3.2. A model for the solar atmosphere 182

4. Ionization in the photosphere 185
5. Calculation of the profiles of absorption lines. The principal lines of neutral and ionized calcium in the Sun 189
5.1. Variation of η with depth 189
5.11. Ionization 190
5.12. Damping 191
5.2. Residual intensity 195
5.3. The line profile and its equivalent width . . . 196
5.4. Comparison of the equivalent widths of lines of neutral and ionized calcium 198
6. The curve of growth 200

X. CONVECTION 206
1. Schwarzschild's criterion for convection in a stellar atmosphere . 206
2. Convection in the solar atmosphere 207
3. Adiabatic change in a dissociating gas 208
4. The convection zone 210
5. Theory of convective movement 212
6. Siedentopf's model 214
7. Numerical application of the equations 216

XI. THE SOLAR CORONA 219
1. Introduction. General description of the corona . . . 219
2. The coronal spectrum 220
3. The nature of the corona 222
4. Distribution of electron density 223
4.1. Electron scattering in the corona 223
4.2. The intensity of coronal light, and the electron density . . 224
5. The high temperature of the corona 227
5.1. The effect of a high-temperature region overlying the photosphere 229
6. Ionization in the corona 231
7. Heat loss in the corona 234
7.1. Conduction 234
7.2. Loss by radiation 234
8. The corona as a source of radio noise 237
8.1. The equation of transfer for radio-frequency radiation . . 240
8.2. The radio-noise spectrum of the corona at the centre of the solar disk 242
9. Some unsolved problems of the corona 244

XII. THE CHROMOSPHERE 246
1. Introduction 246
2. The flash spectrum 247
3. Scale heights 249

4. The low chromosphere 251
4.1. Electron density 251
4.2. Temperature 252
4.3. Ionization 254
5. The high chromosphere 257
5.1. Conduction 257
5.2. Radio emission 259
6. The ultra-violet spectrum of the chromosphere . . . 261

XIII. STARS OTHER THAN THE SUN 266
1. Review of earlier chapters 266
2. The observed characteristics of stars 268
2.1. Spectral types 268
2.2. Stellar magnitudes 270
2.3. Stellar colours 274
2.4. Effective temperatures 277
3. Theoretical work on stellar spectra 280
3.1. Maximum intensities of lines in the spectral sequence . . 280
3.2. Model stellar atmospheres 282
3.21. Incomplete stellar models 283
3.22. Complete stellar models 286
3.23. Determination of stellar diameters from observations of brightness 293

APPENDIX. Useful Constants and Formulae . . . 298
1. Physical constants 298
2. Astronomical constants 298
3. Useful relations 299
4. Physical formulae 299
4.1. Maxwellian distribution of velocities 299
4.2. Saha's formula 300
4.3. Planck's function 300

INDEX OF AUTHORS 301

INDEX OF SUBJECTS 303