

TABLE OF CONTENTS

PREFACE	xi
CHAPTER 8: Radiation Output – R. G. ATHAY	1
1. Introduction	1
2. Basic Concepts and Definitions	4
2.1. Formation of Spectra	4
2.2. Energy Balance	5
2.3. Notation	6
2.4. Escape Probability and Scattering Depth	6
2.5. Escape Coefficient	7
2.6. Creation and Destruction Probabilities	8
2.7. Thermalization and Degradation Lengths	9
2.8. Intra-Atmosphere Exchange Probability	10
2.9. The Source Function	10
2.10. The Transfer Equation	11
3. Spectral Diagnostics	14
3.1. Temperature Diagnostics	14
3.2. Density Diagnostics	16
3.3. Velocity and Magnetic Field Diagnostics	18
3.4. Abundance Diagnostics	20
4. The Role of Radiation in Determining Atmospheric Properties	22
4.1. Photosphere	22
4.2. Line Blanketing and Cooling	24
4.3. The Chromosphere	27
4.4. Characteristics of Chromosphere Radiation Loss	30
4.5. Temperature Minimum	33
4.6. The First Temperature Plateau	34
4.7. The Second Temperature Plateau	35
4.8. The Transition Region	36
4.9. The Corona	37
5. Nonradial Structure	39
5.1. Fluid Motions and Magnetic Fields	39
5.2. Photosphere and Temperature Minimum Region	40
5.3. Chromosphere and Transition Region	41
5.4. Corona	43
6. Temporal Fluctuations	44
7. Challenges for the Future	45
7.1. Radiation Diagnostics	45
7.2. Influence of Radiation on Atmospheric Properties	46
7.3. Observations	47

References	48
CHAPTER 9: Chromospheric Fine Structure – R. G. ATHAY	51
1. Introduction	51
1.1. Role of Fine Structure	51
1.2. Definition of Fine Structure and the Observational Challenge	52
2. Properties of Chromospheric Structure	54
2.1. Network and Supergranule Cells	54
2.2. Network Coarse and Fine Structure	58
2.3. Supergranule Cell Structure	60
2.4. Active Region Structure	61
3. Velocity and Magnetic Structure	61
3.1. Magnetic Structure	61
3.2. Velocity Structure	64
4. Magnetohydrodynamic Structure	65
4.1. A New Look at Fine Structure	65
4.2. Lifting Forces	66
5. Major Problems	67
5.1. Energy Balance	67
5.2. Momentum Balance	68
5.3. The Sun as a Star	68
References	68
CHAPTER 10: Structure, Dynamics, and Heating of the Solar Atmosphere – GERALD W. PNEUMAN and FRANK Q. ORRALL	71
1. Introduction	71
2. Basic Theory and Processes	71
3. Overall Atmospheric Structure	75
4. The Chromosphere—Corona Transition Region and the Base of the Inner Corona	77
4.1. Introduction	77
4.2. Empirical Models of the Mean Temperature Structure	78
4.3. Inhomogeneous and Dynamic Structure of the Transition Shell	80
5. Closed Coronal Regions	82
5.1. Basic Structure	82
5.2. Phenomenology of Coronal Loops	83
5.3. Quasistatic Loop Models in Energy Balance	84
5.4. Evolution and Stability	86
5.5. Systematic Flow	88
5.6. Heating	88
6. Open Coronal Regions and the Coronal Expansion into Interplanetary Space	91
6.1. Introduction	91
6.2. The Solar Wind	91
6.3. Magnetic Fields in the Solar Wind	94
6.4. Coronal Holes	96

6.5. Coronal-Interplanetary Modeling	99
7. Coronal Streamers: Gas-Magnetic Field Interactions in the Solar Corona	100
8. Coronal Activity	105
8.1. The Prominence Phenomena	105
8.1.1. Quiescent Prominences	107
8.1.2. Prominence Support	109
8.1.3. Prominence Stability: Disparition Brusques	111
8.2. Solar Flares	112
8.2.1. Two-Ribbon Flares	113
8.2.2. Compact Flares	117
8.3. Impulsive Flows	118
8.3.1. Surges	118
8.3.2. Sprays	119
8.3.3. Coronal Whips	120
8.4. Coronal Transients	120
References	125
CHAPTER 11: Physical Processes in the Solar Corona – R. ROSNER, B. C. LOW, and T. E. HOLZER	135
1. Introduction	135
2. Transport Theory	136
2.1. Fundamental Parameter Regimes	136
2.2. The ‘Ideal’ Problem	138
2.3. Viscosity	139
2.4. Parallel Thermal Energy Transport	140
2.5. Perpendicular Transport	144
2.6. Some Comments on Model Building	145
3. Magnetohydrodynamic Processes in the Corona	147
3.1. Equilibrium Magnetic Fields	148
3.2. Linear Stability and Nonequilibrium	153
3.3. Time-Dependent Phenomena	161
3.4. Discussion	167
4. Energy and Momentum Balance of Open and Closed Coronal Structures	169
4.1. Coronal Holes and High-Speed Streams	169
4.2. Alfvén Waves in the Lower Solar Atmosphere	169
4.3. Energy Supply to Magnetically Closed Coronal Regions	175
Acknowledgement	176
References	176
CHAPTER 12: Magnetic Energy Storage and Conversion in the Solar Atmosphere – D. S. SPICER, J. T. MARISKA and J. P. BORIS	181
1. Introduction	181
2. Fundamental Concepts	186
2.1. Magnetic Energy Generation	187
2.2. Ideal MHD Theory	189
2.3. Non-MHD Properties	192

2.4. The Concept of ‘Anomalous’ Resistivity	195
2.5. Global Electrodynamic Coupling	198
3. Magnetically Controlled Energy Conversion	204
3.1. Magnetic Modifications of Plasma Transport	204
3.2. Transition Region Structure and Flows	206
3.3. Channeling and Acceleration of Plasma	209
3.4. Channeling and Dissipation of MHD Waves	210
3.5. Anomalous Dissipation of Field-Aligned Currents	213
4. Magnetohydrodynamic Energy Conversion	219
4.1. Magnetic Flux Tube Emergence	219
4.2. Geometric Rearrangements	222
4.3. Reconnection and Magnetic Tearing	226
4.4. Particle Acceleration at a Neutral Sheet	235
4.5. Flare Trigger Mechanisms	236
5. Outstanding Questions	240
Acknowledgements	243
References	244

CHAPTER 13: The Acceleration and Propagation of Solar Flare Energetic
 Particles – M. A. FORMAN, R. RAMATY, and E. G.
 ZWEIBEL

	249
1. Introduction	249
2. Energetic Particles in Solar Flares	250
2.1. Electromagnetic Radiations	250
2.1.1. Radio Emissions	251
2.1.2. Hard X-Rays	251
2.1.3. Gamma Rays	253
2.2. Energetic Particles	256
2.2.1. Energy Spectra and Electron-Proton Correlations	256
2.2.2. Chemical Compositions	260
2.2.3. Isotopic and Ionic Compositions	263
3. Mechanisms of Solar Flare Particle Acceleration	264
3.1. Stochastic Acceleration	264
3.2. Shock Acceleration	272
3.3. Acceleration in Direct Electric Fields	277
4. Solar Flare Particle Spectra in Interplanetary Space	280
5. Summary and Outlook	284
Acknowledgements	285
References	285

CHAPTER 14: Nuclear Processes in Solar Flares – R. RAMATY

	291
1. Introduction	291
2. Nuclear Reactions in Solar Flares	295
2.1. Interaction Models and Properties of the Energetic Particles	295
2.2. Neutron and 2.223 MeV Photon Production	299

2.3. Positron and 0.511 MeV Photon Production	304
2.4. Prompt De-Excitation Line Production	306
3. Implications of Gamma-Ray Observations	312
3.1. Interaction Model, Energetic Particle Spectrum, Number and Energy Content	313
3.2. Time Dependence	317
3.3. The Photospheric ^3He Abundance	318
3.4. Beaming of the Energetic Particles	319
4. Summary	319
Acknowledgements	321
References	321
CHAPTER 15: Solar Radio Emission – MARTIN V. GOLDMAN and DEAN F. SMITH	325
1. Introduction	325
2. Observational Results	327
2.1. Type III Bursts	327
2.1.1. Ground-Based Observations (Above ~ 8 MHz)	327
2.1.2. Spacecraft Observations (Below 1 MHz)	331
2.1.3. Langmuir Waves and Electron Streams	334
2.2. Microwave Bursts	339
2.3. Type II Bursts	341
2.4. Moving Type IV Bursts	342
2.5. Type I Noise Storms	343
3. Theory of Type III Radio Bursts (Radio Emission from Electron Streams)	345
3.1. Overview	345
3.2. Quasilinear Theory	345
3.3. Induced Scatter Off Ions	348
3.4. Wave–Wave Effects of the Nonlinear Refractive and Self-Focusing Variety	349
3.5. Second Harmonic Emission from Langmuir Waves	351
3.6. Fundamental Emission from Langmuir Waves	354
3.7. Density Irregularities and Ion-Acoustic Waves	354
4. Radio Emission from Shock Waves and Current Sheets	355
4.1. Shock Configuration	355
4.2. Generation of Electron Streams by Shock Waves	358
4.3. Radiation Mechanisms	360
5. Radio Emission from Moving Plasmoids and Other Traps	361
5.1. Plasmoid and Other Trapping Configurations	361
5.2. Sources of Electrons in Plasmoids and Traps	364
5.3. Loss Cone and Collisional Electron Losses	366
5.4. Radiation Mechanisms	366
6. Conclusions and Recommendations	370
6.1. Type III Emissions	370
6.2. Type II Bursts	371

6.3. Moving Type IV Bursts	372
6.4. Type I Bursts	372
Acknowledgements	372
References	372
INDEX	377

