

CONTENTS

chapter 1	INTRODUCTION—PROGRAMS FOR THE CONQUEST OF SPACE	1
	DONALD P. LE GALLEY, TRW Space Technology Laboratories	
 1-1	 Physical Quantities To Be Measured	 3
	Micrometeoroids—Cosmic Dust, 3	
	Magnetic Fields, 3	
	Solar Plasma, 4	
	Solar Radiation, 4	
	Emission of Solar Particles, 5	
	Trapped Radiation, 5	
	Man-Made Radiation in Space, 5	
	Cosmic Rays, 6	
	Ionospheric Properties, 6	
 1-2	 Space Programs To Make Physical Measurements	 6
	The Explorer Program, 6	
	Explorer 10, 9	
	Explorer 12, 10	
	Explorer 14, 11	
	Explorer 15, 13	
	Explorer 16, 13	
	Explorer 17, 14	
	The Pioneer Program, 15	
	The Ranger Program, 16	
	The Mariner Program, 20	

	Mariner 1, 20	
	Mariner 2, 20	
	The Orbiting Observatories, 24	
	1. The Orbiting Solar Observatories (OSO), 24	
	2. The Orbiting Geophysical Observatories (OGO), 25	
	3. The Orbiting Astronomical Observatories (OAO), 28	
	Ariel (S-51), 34	
	Alouette (topside sounder), 36	
	The Anna Program, 36	
	Tetrahedral Research Satellite (TRS), 38	
1-3	Summary	38
	References	40

PART I EXPERIMENTAL TECHNIQUES FOR SPACE PHYSICS 43

chapter 2 SPACECRAFT DESIGN FOR SCIENTIFIC MISSIONS 45
CARL D. GRAVES AND ROBERT A. PARK, TRW
 Space Technology Laboratories

2-1	Space Design Requirements Arising from Mission Characteristics	47
	General Requirements, 47	
	Requirements for Specific Missions, 50	
	1. Geophysical Missions, 50	
	2. Solar and Astronomical Observatory Missions, 53	
	3. Interplanetary and Solar Probes, 54	
	4. Planetary Probes, 57	
	5. Lunar and Planetary Landers, 59	
2-2	Experiment/Spacecraft Interface Requirements	61
	General Experiment/Spacecraft Interfaces, 62	
	Interfaces between the Spacecraft and Specific Types of Experiments, 66	
	1. High-Energy Radiation Measurements, 67	
	2. Solar Plasma Measurements, 68	
	3. Magnetic Field Measurements, 69	
	4. Micrometeoroid (Cosmic Dust) Measurements, 70	
	5. Radio Wave Measurements, 71	
	6. Optical Measurements, 71	
	7. Atmospheric Composition Measurements, 73	
	8. Planetary Surface Measurements, 74	
	9. Biological Measurements, 75	

2-3	Integration and Test Requirements	76
	Functional Testing, 76	
	Environmental Testing, 77	
2-4	The Spacecraft Design Evaluation	78

chapter 3 **EXPERIMENTAL TECHNIQUES EMPLOYED IN SPACE PHYSICS** 82

JOHN W. LINDNER, TRW Space Technology Laboratories

3-1	Magnetic-Field Measurements	82
	Search-Coil Magnetometer, 83	
	Flux-Gate Magnetometer, 84	
	Precession Magnetometers, 85	
3-2	Micrometeoroid Detectors	88
3-3	Plasma Probes	89
	Faraday Cup, 90	
	Electrostatic Analyzer, 90	
3-4	Optical Instruments	91
	Ultraviolet Ionization Chamber, 91	
	Grating Spectrometer, 92	
	Telescopes, 94	
	Infrared Radiometer, 94	
3-5	Radiation Detectors	95
	Ionization Chamber, 95	
	Geiger Counter, 97	
	Proportional Counter, 98	
	Scintillation Counters, 98	
	Solid-State Detectors, 99	
	Uses of Radiation Sensors, 99	
3-6	Atmospheric Measurements	103
	Magnetic Spectrometer, 103	
	Bennett Radio-Frequency Mass Spectrometer, 103	
	Langmuir Probe, 105	
	References	105

PART II	SOLAR AND PLANETARY PHYSICS	107
chapter 4	SOLAR PHYSICS AND SOLAR RADIATION LEWIS LARMORE , Lockheed-California Company	109
4-1	Physical Properties	110
4-2	Observable Features Permanent Features, 113 Transient Features, 116	113
4-3	The Solar Spectrum The Visible Spectrum, 121 The Ultraviolet Spectrum, 122 The X-ray Spectrum, 124 References General References	120 125 126
chapter 5	PHYSICS OF THE PLANETS A. G. W. CAMERON , Goddard Institute for Space Studies, National Aeronautics and Space Administration	127
5-1	The Origin of the Planetary Atmospheres	128
5-2	The Atmosphere of the Earth	133
5-3	The Atmosphere of Mercury	138
5-4	The Atmosphere of Venus	139
5-5	The Atmosphere of Mars	145
5-6	The Atmospheres of the Giant Planets	152
5-7	The Surface of the Moon	155
5-8	Planetary Interiors References	158 160
chapter 6	THE STRUCTURE AND PHYSICS OF THE UPPER ATMOSPHERE THOMAS E. VAN ZANDT AND ROBERT W. KNECHT , Central Radio Propagation Laboratory, National Bureau of Standards	166
6-1	The Structure of the Ionosphere The D Region, 168	168

	1. Techniques of Observation, 168	
	2. Summary of Observations, 168	
	The E Region, 174	
	1. The Daytime E Layer, 174	
	2. The Nighttime E and F ₁ Regions, 177	
	3. The Sporadic E, 183	
	The F Region, 185	
	1. The F ₁ Layer, 185	
	2. The F ₂ Layer, 186	
	The Heliosphere, 194	
	The Protonosphere, 195	
6-2	The Physics of the Upper Atmosphere	196
	The Neutral Atmosphere, 196	
	1. The Barometric Equation, 196	
	2. Pressure, Density, and Temperature between 50 and 200 km, 199	
	3. Composition, 199	
	4. Model Atmospheres in the 90 to 100 km Region, 204	
	5. The Atmosphere above 200 km, 205	
	The Physics of the Ionosphere, 207	
	1. Photoionization, 207	
	2. Recombination, 214	
	3. Transport of Charge, 217	
	4. Diffusive Equilibrium in a Plasma, 219	
	5. Electron Temperatures in the Ionosphere, 221	
6-3	Conclusion	221
	References	221
chapter 7	AURORA AND GEOMAGNETIC STORMS	226
	SYDNEY CHAPMAN , University of Alaska and High Altitude Observatory, Boulder	
7-1	The Interrelated Observations	227
7-2	History and Background	229
7-3	Geographical Distribution of Long-term Average Auroral Frequency	230
7-4	Variations of Auroral Frequency during the Sunspot Cycle and the Year	233
7-5	Isochasms and Auroral Theory	234
7-6	Conjugate Auroral and Other Relationships	241
7-7	Auroral Theory and Magnionics	241

7-8	The Effective Electric Current Density Associated with the Plasma in the Magnetosphere	248
7-9	Auroral Morphology	251
7-10	The Auroral Spectrum	256
7-11	Artificial Auroras	258
7-12	Auroras and Geomagnetic Storms: Theory and Speculation	259
	Appendix. Photography of the Aurora from Above	263
	References	265
	General References	269
 chapter 8	 MICROMETEOROIDS BERNARD HAMERMESH, TRW Space Technology Laboratories	 270
8-1	Indirect Techniques	271
8-2	Direct Techniques	273
	Microphone Sensors, 273	
	Impact Light Flash Sensors, 275	
	Impact Ionization Detectors, 276	
	Puncture Counters, 280	
	Detector Development, 284	
8-3	Results of Direct Measurements	286
8-4	Effects of Micrometeoroids on Objects in Space	292
	Summary	296
	References	296
 PART III FIELDS AND PLASMAS IN INTER- PLANETARY SPACE		 299
 chapter 9	 THE GEOMAGNETIC FIELD LAURENCE J. CAHILL, JR., NASA Headquarters	 301
9-1	Historical Background	303
9-2	Source of the Main Geomagnetic Field	304
9-3	The Main Field and Its Variations	305
9-4	Ionospheric Currents	310
9-5	Satellite Mapping of the Geomagnetic Field	316
9-6	The Search for the Ring Current	320

9-7	The Outer Geomagnetic Field	327
9-8	Future Magnetic Experiments	343
	References	346

chapter 10 INTERPLANETARY MAGNETIC FIELDS 350

EDWARD J. SMITH, Jet Propulsion Laboratory

10-1	The Origin of Interplanetary Magnetic Fields	352
10-2	Theoretical Models of the Interplanetary Magnetic Field	358
	The Spiral Solar-Interplanetary Field, 358	
	Solar-Interplanetary Magnetic Loops, 360	
10-3	The Existence and Properties of the Large-Scale Interplanetary Magnetic Field	363
10-4	The Disordering of Interplanetary Magnetic Fields	374
	Hydromagnetic Waves, 376	
	Hydromagnetic Shocks, 377	
	Thermal Instabilities, 380	
	Nonuniform Solar-Wind Velocity, 381	
	Experimental Evidence, 381	
10-5	Observations of the Disturbed Interplanetary Magnetic Field	382
	Appendix A	385
	The Basic Equations, 385	
	Some Kinetic Properties of Solar Plasma, 388	
	Magnetic Field Diffusion, 390	
	Field Transport, 391	
	Appendix B	393
	The Geometry of Spiral Interplanetary Magnetic Fields, 393	
	References	394

chapter 11 THE SOLAR PLASMA—ITS DETECTION MEASUREMENT AND SIGNIFICANCE 397

WILLIAM BERNSTEIN, TRW Space Technology Laboratories

11-1	Indirect Observations	399
	Geomagnetic Storms, 399	
	The Plasma-Magnetic-Field Configuration Derived from Cosmic-Ray Data, 399	

	The Heating of the Terrestrial Upper Atmosphere and Steady-State Geomagnetic-Field Fluctuations, 401	
	The Zodiacal-Light and Night-Sky Brightness Observations, 404	
	Comet-Tail Observations, 406	
	Auroras and Auroral-Zone Phenomena, 409	
11-2	Direct Plasma-Probe Experiments	411
	Experimental Techniques, 411	
	Experimental Results, 419	
11-3	Composition of the Solar Wind and Its Significance	426
	Theoretical Expectations and Difficulties in Direct Measurement, 426	
	Relationship of the Solar Wind to the Lunar Atmosphere, 428	
	Relationship between the Solar Wind and Planetary Atmospheres, 431	
	The Existence of a Static Interplanetary Medium, 432	
11-4	Conclusions	433
	References	433
chapter 12	THE SOLAR WIND AND ITS INTERACTION WITH MAGNETIC FIELDS	437
	FREDERICK L. SCARF, TRW Space Technology Laboratories	
12-1	The Hydrodynamic Coronal Models	439
12-2	Stationary Flow without Rotation or Magnetic Fields	443
12-3	The Interplanetary Magnetic Field	450
12-4	The Solar-Wind-Interplanetary Field Interaction	457
12-5	The Solar-Wind-Geometric-Field Interaction	462
12-6	Outlook	471
	References	471
chapter 13	HYDROMAGNETIC WAVES IN SPACE	474
	GORDON J. F. MAC DONALD, Institute of Geophysics and Planetary Physics, University of California, Los Angeles	
13-1	Plasma in the Magnetosphere and Nearby Space	476
13-2	Description of Hydromagnetic Waves	481
13-3	Observation of Hydromagnetic Waves at the Earth's Surface	494
13-4	Hydromagnetic Waves in Space	498
	References	500

PART IV HIGH ENERGY RADIATION IN SPACE 503

chapter 14 THE TRAPPED-RADIATION ZONES 505

BRIAN J. O'BRIEN, Department of Space Science,
Rice University

14-1	Dynamics of Particle Motion	508
	Periodic Motions, 508	
	Summary, 510	
	Adiabatic Invariants, 511	
	The (L,B) System of Mapping Particle Motions, 516	
	Examples of a Consummate Experiment, 519	
14-2	Historical Review	521
	Discovery, 521	
	Exploration of the Spatial Distribution, 538	
	The Constituent Particles, 540	
14-3	Status of Present Experimental Findings	543
	General, 543	
	Positively Charged Constituent, 544	
	1. Particle Type, 544	
	2. Spatial Distribution, 545	
	3. Energy Distribution, 547	
	4. Angular Distributions, 548	
	5. Temporal Dependence, 549	
	Negatively Charged Constituents, 551	
	1. Particle Type, 551	
	2. Spatial Distribution, 551	
	3. Energy Distribution, 554	
	4. Angular Distributions, 556	
	5. Temporal Variations, 557	
14-4	Mechanisms for Generating and Losing Van Allen Radiation	559
	General, 559	
	Albedo Neutrons as a Source, 560	
	Other Sources and Loss Mechanisms, 565	
	The Outer Zone and Auroras, 566	
14-5	Concluding Remarks	568
	References	569
	Popular Review Articles	572

chapter 15	THE EFFECTS OF HIGH-ALTITUDE EXPLOSIONS	573
	WILMOT N. HESS, NASA-Goddard Space Flight Center	
15-1	A Bomb as a Source of Charged Particles	575
15-2	The Neutron Source	576
15-3	Particle Motion	579
15-4	Early History of Starfish	582
15-5	Synchrotron Radiation	583
15-6	Satellite Data on Starfish	585
15-7	Radiation Damage	591
15-8	Effects on the Natural Radiation Belt	593
15-9	The Russian High-Altitude Explosions	594
15-10	Changes of the Electron Energy Spectrum with L Time after Fission, 597 Particle Cooling in an Expanding Bubble, 597	597
15-11	Decay of the Electrons $L < 1.7$, 601 $L > 1.7$, 606 References	601 608
 chapter 16	 ENERGETIC SOLAR PARTICLES	 611
	KINSEY A. ANDERSON, Department of Physics and Space Sciences Laboratory, University of California, Berkeley	
16-1	Historical Summary	613
16-2	Properties of Energetic Solar Radiation	623
16-3	Some Astrophysical Consequences of Solar Energetic Radiation	639
16-4	Effects on Planetary Atmospheres References	644 656
 chapter 17	 COSMIC RAYS IN SPACE	 659
	ALAN ROSEN AND JOSEPH L. VOGL, TRW Space Technology Laboratories	
17-1	Experimental Observations	660
17-2	Experimental Results Composition, 669 Electrons and Gamma Rays, 671	669

	The Energy Spectrum and Particle Flux, 673	
	Time Variations, 674	
	Forbush Decrease, 675	
	Eleven-Year Cycle, 675	
	The Low-Energy Portion of the Primary Cosmic Spectrum, 677	
	Directional Characteristics of Galactic Cosmic Rays, 677	
	Energy Density, 678	
	Cosmic-Ray Measurements in Deep Space, 678	
17-3	Galactic Structure	679
	Magnetic Cavities in the Universe, 682	
	Galactic Origin of Cosmic Rays, 682	
17-4	The Origin of Cosmic Rays	684
	Sources of Energetic Particles, 685	
	The Sun, 685	
	Other Stars, 686	
	Novae and Supernovae, 686	
	Extragalactic Radio Sources, 686	
17-5	Acceleration Mechanisms for Cosmic Rays	688
	Fermi Acceleration, 688	
	Deduction of an Energy Spectrum, 691	
	Anisotropy, 692	
	Outlook, 692	
	Appendix A. Definition of Terms and Basic Equations	693
	The Omnidirectional Intensity, 693	
	The Unidirectional Intensity and Its Relationship to the Omnidirectional Intensity, 693	
	The Integral Spectral Distribution n , Sometimes Called the Integral Energy Spectrum, 694	
	Appendix B. Deflection of Charged Nuclei by the Geomagnetic Field	697
	References	702

chapter 18	SPACE DOSIMETRY	705
	GEORGE W. CRAWFORD, Southern Methodist University	

18-1	Statement of the Problem	706
18-2	Techniques of Calculating Absorbed Dose	709
18-3	Interaction between Protons and Atomic Electrons	710
18-4	Interaction between Protons and Nuclei	714
18-5	Interactions between Neutrons and Nuclei	716

18-6	Interactions between Incident Electrons and Atomic Electrons	717
18-7	Interactions between Electrons and the Electric Field of the Absorber Nuclei	718
18-8	Interactions between Photons and Atomic Electrons	721
18-9	Interactions between Photons and Nuclei	723
18-10	Dose Calculations	723
18-11	Calculated Dose Rates in Space	725
18-12	Techniques of Measuring Absorbed Dose	731
18-13	Direct Dose Measurements	731
18-14	Ionization Current Techniques	732
18-15	Future Space Dosimetry	736
	References	739

INDEX	743
-------	-----

