

## Contents

<i>Preface</i>	<i>page</i> ix
<i>Acknowledgements</i>	xii
1 The Earth's main field	1
1.1 Introduction	1
1.2 Magnetic Components	4
1.3 Simple Dipole Field	8
1.4 Full Representation of the Main Field	15
1.5 Features of the Main Field	34
1.6 Charting the Field	41
1.7 Field Values for Modeling	47
1.8 Earth's Interior as a Source	51
1.9 Paleomagnetism	58
1.10 Planetary Fields	62
1.11 Main Field Summary	63
1.12 Exercises	65
2 Quiet-time field variations and dynamo currents	67
2.1 Introduction	67
2.2 Quiet Geomagnetic Day	68
2.3 Ionosphere	74
2.4 Atmospheric Motions	81
2.5 Evidence for Ionospheric Current	86
2.6 Spherical Harmonic Analysis of the Quiet Field	92
2.7 Lunar, Flare, Eclipse, and Special Effects	102
2.8 Quiet-Field Summary	108
2.9 Exercises	109
3 Solar–terrestrial activity	111
3.1 Introduction	111
3.2 Quiet Sun	113
3.3 Active Sun, Sunspots, Fields, and Coronal Holes	116
3.4 Plages, Prominences, Filaments, and Flares	122
3.5 Mass Ejections and Energetic Particle Events	127
3.6 Interplanetary Field and Solar Wind Shocks	128
3.7 Solar Wind–Magnetosphere Interaction	135
3.8 Geomagnetic Storms	139

3.9	Substorms	142
3.10	Tail, Ring, and Field-Aligned Currents	144
3.11	Auroras and Ionospheric Currents	152
3.12	Radiation Belts	165
3.13	Geomagnetic Spectra and Pulsations	168
3.14	High Frequency Natural Fields	173
3.15	Geomagnetic Indices	175
3.16	Solar–Terrestrial Activity Summary	184
3.17	Exercises	186
4	Measurement methods	189
4.1	Introduction	189
4.2	Bar Magnet Compass	190
4.3	Classical Variometer	194
4.4	Astatic Magnetometer	195
4.5	Earth-Current Probe	196
4.6	Induction-Loop Magnetometer	198
4.7	Spinner Magnetometer	200
4.8	Fluxgate (Saturable-Core) Magnetometer	201
4.9	Proton-Precession Magnetometer	203
4.10	Optically Pumped Magnetometer	205
4.11	Zeeman-Effect Magnetometer	210
4.12	Cryogenic Superconductor Magnetometer	212
4.13	Gradient Magnetometer	213
4.14	Comparison of Magnetometers	215
4.15	Observatories	215
4.16	Location and Direction	219
4.17	Field Sampling and Data Collection	219
4.18	Tropospheric and Ionospheric Observations	221
4.19	Magnetospheric Measurements	222
4.20	Instrument Summary	225
4.21	Exercises	226
5	Applications	228
5.1	Introduction	228
5.2	Physics of the Earth's Space Environment	229
5.3	Satellite Damage and Tracking	230
5.4	Induction in Long Pipelines	233
5.5	Induction in Electric Power Grids	235
5.6	Communication Systems	237
5.7	Disruption of GPS	239
5.8	Structure of the Earth's Crust and Mantle	239
	5.8.1 Surface Area Traverses for Magnetization Fields	241
	5.8.2 Aeromagnetic Surveys	241

5.8.3	Conductivity Sounding of the Earth's Crust	246
5.8.4	Conductivity of the Earth's Upper Mantle	251
5.9	Ocean Bottom Studies	253
5.10	Continental Drift	255
5.11	Archeomagnetism	257
5.12	Magnetic Charts	257
5.13	Navigation	258
5.14	Geomagnetism and Weather	259
5.15	Geomagnetism and Life Forms	262
5.16	Solar–Terrestrial Disturbance Predictions	269
5.17	Magnetic Frauds	271
5.17.1	Body Magnets	277
5.17.2	Prediction of Earthquakes	277
5.18	Summary of Applications	278
5.19	Exercises	279
Appendix A	Mathematical topics	280
A.1	Variables and Functions	280
A.2	Summations, Products, and Factorials	282
A.3	Scientific Notations and Names for Numbers	282
A.4	Logarithms	283
A.5	Trigonometry	284
A.6	Complex Numbers	285
A.7	Limits, Differentials, and Integrals	287
A.8	Vector Notations	289
A.9	Value Distributions	291
A.10	Correlation of Paired Values	294
Appendix B	Geomagnetic organizations, services, and bibliography	296
B.1	International Unions and Programs	296
B.2	World Data Centers for Geomagnetism	298
B.3	Special USGS Geomagnetism Website	303
B.4	Special Geomagnetic Data Sets	304
B.5	Special Organization Services	306
B.6	Solar–Terrestrial Activity Forecasting Centers	309
B.7	Bibliography for Geomagnetism	312
B.8	Principal Scientific Journals for Geomagnetism	313
Appendix C	Utility programs for geomagnetic fields	315
C.1	Geomagnetic Coordinates 1940–2005	315
C.2	Fields from the IGRF Model	316
C.3	Quiet-Day Field Variation, Sq	316
C.4	The Geomagnetic Disturbance Index, Dst	317
C.5	Location of the Sun and Moon	318

C.6	Day Number	318
C.7	Polynomial Fitting	319
C.8	Quiet-Day Spectral Analysis	319
C.9	Median of Sorted Values	319
C.10	Mean, Standard Deviation, and Correlation	320
C.11	Demonstration of Spherical Harmonics	320
C.12	Table of All Field Models	321
	<i>References</i>	322
	<i>Index</i>	332