CONTENTS

PREFACE. v

CHAPTER 1. INTRODUCTORY REMARKS. 1

CHAPTER 2. MAIN MAGNETIC FIELD OF THE EARTH 5

World's distribution of the geomagnetic field 5
Elements of the geomagnetic field 5
Magnetic charts 9
Spherical harmonic analysis of the main field 9
Dipole field. 10
Eccentric dipole 11

CHAPTER 3. THEORY OF STEADY DYNAMO 13
Theories of the origin of the earth's magnetism 13
Permanent magnetization 14
Free decay of electric current 14
Gyromagnetic effect 15
Rotating electric charge. 15
Electromagnetic induction by magnetic storms 15
Thermoelectric effect. 16
Hall effect 16
Compression effect 17
Rotation of a massive body 18
Twisted-kink theory 19
Basic idea of the dynamo 19
Equations for a homogeneous dynamo 21
Physical discussions relating to the homogeneous dynamo 22
Convection current and magnetic lines of force. 24
Bullard process 27
Feedback mechanism proposed by Bullard 27
Eigen-value problem 29
Additional discussion 32
Inglis model 32
Visual aid by Inglis 32
Equations for the Inglis model 35
Non-dimensional form of the equations 38
Steady-state solution 38
Steady state of a model of manageable size in a laboratory 40
Inglis model with the size of the earth's core. 40
Backus and Herzenberg dynamos 42
Lowes and Wilkinson's experiment. 45

CHAPTER 4. STABILITY OF THE DIPOLE FIELD 47
Fundamental equations for small M.H.D. disturbances given to a conducting fluid body 47
M.H.D. oscillation of a perfectly conducting fluid sphere placed in a uniform magnetic field 49
Effect of the Coriolis force 55
Stability of the earth's dynamo 57

CHAPTER 5. THEORY OF NON-STEADY DYNAMO 59
Finite-amplitude oscillation of a disk dynamo 59
Oscillation of a system of disk dynamo 61
Disk dynamo with a heat engine 64
Time-dependent behaviour of the Inglis model 67

CHAPTER 6. GEOMAGNETIC SECULAR VARIATION 72
Secular variation as observed by instruments 73
Analysis of the secular variation. 73
Decrease in the dipole moment 77
Secular variation during historical and geological times 78
Reversal of the geomagnetic dipole. 80
Evidence from palaeomagnetic studies 80
Field intensity during a reversal 81
Westward drift of the geomagnetic field 83
Non-drifting secular variation 86
Drift of the eccentric dipole 90
Fluctuation in the length of day and geomagnetic secular variation 91

CHAPTER 7. THEORY OF SECULAR VARIATION. 94
Core–mantle coupling and the westward drift 95
Rigid-sphere model 95
Diffusion of toroidal field 96
Mechanical couple exerted to the mantle 99
Time-dependent core–mantle coupling. 100
Oscillation of the quadrupole field in relation to the northward shift 102
Growth and decay of non-drifting field 106
Rigid-rotator model 106
Poloidal fields associated with uplifting of toroidal field by convective motion 109

CHAPTER 8. ELECTROMAGNETIC INDUCTION WITHIN THE EARTH BY DAILY VARIATION 115
Analysis of solar daily variation (Sq) 115
Analysis of lunar daily variation (L) 116
Numerical method for calculating a magnetic potential 117
Method of graphical integration 117
Method of residuals 118
Surface integral method for the analysis of a potential 121

CHAPTER 9. THEORY OF ELECTROMAGNETIC INDUCTION IN A SPHERICAL BODY 126
Fundamental equations in a non-uniform conductor 126

Conductors with spherical symmetry . . . 128
Uniform sphere model . . . 129
Non-uniform sphere model when $\sigma=\sigma_0\varrho^{-l}$ . . . 131
Spherical shell . . . 132
Use of high-speed computer . . . 132

CHAPTER 10. ELECTROMAGNETIC INDUCTION BY VARIOUS VARIATIONS . . . 135
Sudden storm commencement (*s.s.c.*) . . . 135
Storm main phase (*Dst*) . . . 137
Geomagnetic bay . . . 138
Solar flare effect (*s.f.e.*) . . . 139
Auroral jet . . . 142
Other variations . . . 142

CHAPTER 11. THEORY OF ELECTROMAGNETIC INDUCTION IN AN EARTH HAVING A PLANE SURFACE . . . 144
Fundamental equations . . . 144
Elementary solutions . . . 144
Elementary solutions of the first type . . . 145
Elementary solutions of the second type . . . 147
Indeterminate case for induction by a uniform field . . . 148
Relation between external and internal parts of the geomagnetic field over a plane earth . . . 149
Line of magnetic dipoles over a uniform earth—a two-dimensional problem . . . 151

CHAPTER 12. THEORY OF ELECTROMAGNETIC INDUCTION IN A THIN SHEET OF CONDUCTOR . . . 154
General equations . . . 154
Plane sheet . . . 156
Fundamental characteristics of electromagnetic induction in a uniform plane sheet . . . 156
Electromagnetic induction in a uniform plane sheet by a magnetic dipole . . . 157
Non-uniform plane sheet over a uniform semi-infinite conductor . . . 159
Plane sheet with ϱ which is a periodic function of x, 163 — Sudden change in inducing field, 167
Anisotropic plane sheet over a uniform semi-infinite conductor . . . 167
Spherical sheet . . . 170
Uniform spherical sheet . . . 170
Non-uniform or anisotropic spherical sheets . . . 173
Hemispherical sheet . . . 173
Electromagnetic coupling between a hemispherical sheet and an underlying conductor . . . 179
Hemispherical ocean and *Sq* . . . 183
Induction in a disk . . . 184
Use of relaxation method . . . 186
Two-dimensional problem . . . 188
Axisymmetric problem . . . 191
Hole-in-a-plate problem . . . 195
Model experiment . . . 197

CHAPTER 13. THEORY OF ELECTROMAGNETIC INDUCTION IN A CYLINDER: TWO-DIMENSIONAL PROBLEMS 199
Circular cylinder 199
Electromagnetic coupling between a circular cylinder and an underlying layer 200
Response for a rapid change, 202
Elliptic cylinder 205
Small flattening and moderate conductivity 208
Thin elliptic cylinder 209
Highly conducting elliptic cylinder 210

CHAPTER 14. SHIELDING EFFECT OF THE MANTLE AND SECULAR VARIATION. 213
Plane slab model 213
Time-dependent dipole at the core–mantle boundary. 217

CHAPTER 15. OVERALL DISTRIBUTION OF THE ELECTRICAL CONDUCTIVITY IN THE MANTLE 221
Conductivity distribution as inferred from geomagnetic variations arising from external sources 221
Uniform core model 222
Second approximation of the conductivity distribution 223
Results from secular variation 224
Overall distribution of the conductivity 225
Conduction mechanism. 226
Geophysical significance of the conductivity distribution 228
Temperature distribution in the mantle derived from the conductivity distribution. 228
Olivine–spinel transition in the upper mantle. 228

CHAPTER 16. ELECTRICAL CONDUCTIVITY IN THE CORE 231
Physical state in the core 231
Geophysical discussions 231

CHAPTER 17. POSSIBLE EFFECT OF THE OCEAN ON GEOMAGNETIC VARIATIONS 235
Time constant of an ocean 235
Observation on a floating ice station 237
Edge effect at the margin of an ocean 238
Observation on islands 242

CHAPTER 18. EARTH-CURRENTS AND MAGNETO-TELLURICS . . . 243
Earth-current observation 243
Electric and magnetic fields at the surface of a uniform plane earth. 245
Earth-currents in a layered earth. 246
Anisotropy of earth-currents 248
Magneto-telluric method and its limitations 250
Magneto-telluric techniques 250
Comment on the plane-wave assumption 251
Limitations of magneto-telluric method 252

CHAPTER 19. CONDUCTIVITY ANOMALY IN THE CRUST AND MANTLE 256
Anomalies of geomagnetic variations in Japan 257
Central Japan anomaly for geomagnetic bay and similar variation 257
Anomaly of *s.s.c.* 261
Anomaly of *s.f.e.* 262
Anomaly of *Sq* 263
Anomaly of *Dst* 264
Possible cause of the anomalies of geomagnetic variations in Japan 265
Anomalies in Europe 267
Northern Germany anomaly 268
Göttingen anomaly 271
Ponza–Capri anomaly 271
Czechoslovakian, Hungarian and Rumanian anomalies 272
Anomalies in Canada 273
Alert anomaly 275
Mould Bay anomaly 278
Anomalies in U.S.A. 280
Californian coast anomaly 280
Sierra anomaly 283
Texas anomaly 283
Anomalies in Australia 284
Geophysical significance of the conductivity anomalies in the crust and mantle 286

REFERENCES 289

AUTHOR INDEX 301

SUBJECT INDEX 304