

# CONTENTS

## I. CLASSICAL FOUNDATIONS

1. The Macroscopic versus Microscopic Field Equations . . . . .	1
2. Correlation of the Microscopic and Macroscopic Equations . . . . .	3
3. Proof of the Preceding Correlation Formulae . . . . .	7
4. Relation between the Index of Refraction and Dielectric Constant . . . . .	13
5. The Local Field . . . . .	14
6. The Force Equation . . . . .	17
7. The Lagrangian and Hamiltonian Functions . . . . .	19
8. Larmor's Theorem . . . . .	22
9. The Fundamental Theorem of Statistical Mechanics . . . . .	24

## II. CLASSICAL THEORY OF THE LANGEVIN-DEBYE FORMULA

10. Polar versus Non-polar Molecules . . . . .	27
11. Rudimentary Proof of the Langevin-Debye Formula . . . . .	30
12. More Complete Derivation of the Langevin-Debye Formula . . . . .	32
13. Derivation of a Generalized Langevin-Debye Formula . . . . .	37

## III. DIELECTRIC CONSTANTS, REFRACTION, AND THE MEASUREMENT OF ELECTRIC MOMENTS

14. Relation of Polarity to the Extrapolated Refractive Index . . . . .	42
15. Effect of Infra-Red Vibration Bands . . . . .	45
16. Independence of Temperature of the Index of Refraction. . . . .	54
17. Dispersion at Radio Frequencies . . . . .	54
18. The Dielectric Constants of Solutions . . . . .	56
19. Numerical Values of the Electric Moments of Various Molecules. Comparison of the Different Methods . . . . .	60
20. Dielectric Constants and Molecular Structure . . . . .	70
21. Optical Refractivities and Molecular Structure . . . . .	82
22. Saturation Effects in Electric Polarization . . . . .	85

## IV. THE CLASSICAL THEORY OF MAGNETIC SUSCEPTIBILITIES

23. Conventional Derivation of the Langevin Formulae for Para- and Diamagnetism . . . . .	89
24. Absence of Magnetism with Pure Classical Statistics . . . . .	94
25. Alternative Proof of Miss Van Leeuwen's Theorem . . . . .	97
26. Absence of Diamagnetism from Free Electrons in Classical Theory . . . . .	100
27. Inapplicability of Classical Statistics to any Real Atomic System . . . . .	102

## V. SUSCEPTIBILITIES IN THE OLD QUANTUM THEORY, CONTRASTED WITH THE NEW

28. Historical Survey . . . . .	105
29. Weak and Strong Spacial Quantization . . . . .	108
30. Spectroscopic Stability in the New Quantum Mechanics . . . . .	111
31. Effect of a Magnetic Field on the Dielectric Constant . . . . .	113

## VI. QUANTUM-MECHANICAL FOUNDATIONS

32. The Schrödinger Wave Equation . . . . .	122
33. Construction of the Heisenberg Matrix Elements by Use of the Wave Functions . . . . .	124
34. Perturbation Theory . . . . .	131
35. Matrix Elements of a Perturbed System. Proof of Spectroscopic Stability . . . . .	137
36. Formulae for the Electric and Magnetic Moments of a Stationary State . . . . .	143
37. The Rotating Dipole in an Electric Field . . . . .	147
38. The Electron Spin . . . . .	155
39. Orbital and Spin Angular Momentum Matrices . . . . .	159
40. Russell-Saunders Coupling; Spectroscopic Notation . . . . .	162
41. Classical Analogues of the Angular Momentum Matrices, and the Correspondence Principle . . . . .	169
42. The Anomalous Zeeman Effect in Atomic Spectra . . . . .	172
43. The Diamagnetic Second-Order Zeeman Term . . . . .	178

## VII. QUANTUM-MECHANICAL DERIVATION OF THE LANGEVIN-DEBYE FORMULA

44. First Stages of Calculation . . . . .	181
45. Derivation of the Langevin-Debye Formula with Special Models	183
46. General Derivation of the Langevin-Debye Formula . . . . .	186
47. Limit of Accuracy of the Langevin-Debye Formula . . . . .	197

## VIII. THE DIELECTRIC CONSTANTS AND DIAMAGNETIC SUSCEPTIBILITIES OF ATOMS AND MONATOMIC IONS

48. The Dielectric Constant of Atomic Hydrogen and Helium . . . . .	203
49. The Diamagnetism of Atoms, especially Hydrogen and Helium	206
50. Adaptation to Other Atoms by Screening Constants . . . . .	209
51. Polarizability of the Atom-Core from Spectroscopic Quantum Defect . . . . .	215
52. Ionic Refractivities and Diamagnetic Susceptibilities . . . . .	220

## IX. THE PARAMAGNETISM OF FREE ATOMS AND RARE EARTH IONS

53. Adaptation of Proof of Langevin-Debye Formula given in § 46	226
54. Multiplet Intervals Small compared to $kT$ . . . . .	229
55. Multiplet Intervals Large compared to $kT$ . . . . .	232
56. Multiplet Intervals comparable to $kT$ . . . . .	235
57. Susceptibilities of Alkali Vapours . . . . .	238
58. Susceptibilities of the Rare Earths . . . . .	239
59. The Special Cases of Europium and Samarium . . . . .	245
60. Temperature Variation in the Rare Earths. The Gyromagnetic Ratio . . . . .	249
61. Saturation Effects . . . . .	257
62. Lack of Influence of Nuclear Spin . . . . .	259

## X. THE PARA- AND DIAMAGNETISM OF FREE MOLECULES

63. Spectral Notation and Quantization in Diatomic Molecules . . . . .	262
64. Multiplet Intervals Small compared to $kT$ . . . . .	264
65. Multiplet Intervals Large compared to $kT$ . . . . .	265

CONTENTS

xi

66. The Oxygen Molecule . . . . .	266
67. The Nitric Oxide Molecule . . . . .	269
68. Polyatomic Molecules . . . . .	272
69. The Diamagnetism of Molecules . . . . .	276
70. Absence of Magneto-Electric Directive Effects . . . . .	279

XI. THE PARAMAGNETISM OF SOLIDS, ESPECIALLY SALTS  
OF THE IRON GROUP

71. Delineation of Various Cases . . . . .	282
72. Salts and Solutions Involving the Iron Group . . . . .	284
73. Quenching of Orbital Magnetic Moment by Asymmetrical Ex- ternal Fields . . . . .	287
74. Further Discussion of Salts of the Iron Group . . . . .	297
75. The Palladium, Platinum, and Uranium Groups . . . . .	311

XII. HEISENBERG'S THEORY OF FERROMAGNETISM; FUR-  
THER TOPICS IN SOLIDS

76. The Heisenberg Exchange Effect . . . . .	316
77. Heisenberg's Theory of Ferromagnetism . . . . .	322
78. Proof of Formulae for Mean and Mean Square Energy . . . . .	340
79. Magneto-caloric and Magnetostrictive Effects . . . . .	343
80. Feeble Paramagnetism . . . . .	347
81. The Diamagnetism of Free Electrons in Quantum Mechanics . . . . .	353

XIII. BRIEF SURVEY OF SOME RELATED OPTICAL PHE-  
NOMENA

82. The Kramers Dispersion Formula . . . . .	361
83. The Kerr Effect . . . . .	366
84. The Faraday Effect . . . . .	367

INDEX OF AUTHORS . . . . .	375
----------------------------	-----

SUBJECT INDEX . . . . .	380
-------------------------	-----