

CONTENTS

PREFACE	vii
ACKNOWLEDGMENTS	ix
I. PHILOSOPHY OF SCIENCE	1
Introduction	1
Philosophy of Science	3
Truth	4
Significant Questions in Science	7
II. CLASSICAL PRECURSORS FOR THE CONCEPTS OF MODERN PHYSICS	9
Galileo Galilei	9
The Thought Experiment	9
Galileo's Principle of Inertia	9
Laws of Motion in Two- and Three-Dimensional Space	11
Galileo's Principle of Relativity	11
Threads of Truth — Astronomy	12
Rene Descartes	13
Baruch Spinoza	14

Isaac Newton	15
Newton's Three Laws of Motion	16
Newton's Law of Universal Gravitation	16
Newton's Concepts	18
Newton's Optics	19
III. NINETEENTH CENTURY PHYSICS: ATOMISM AND CONTINUITY	21
The Ideal Gas Law	22
Heat and the Conservation of Energy	24
The Laws of Thermodynamics and Atomism	25
Ludwig Boltzmann's and Ernst Mach's Philosophy of Science	27
Agreements between Boltzmann and Mach and 'Mach's Principle'	28
The Continuous Field Concept	29
IV. EARLY ANOMALIES AND ELEMENTARY PARTICLES	34
The Perihelion Precession of Mercury's Orbit	34
The Michelson–Morley Experiment	35
Blackbody Radiation and the Photon	37
The Electron	39
The Quantization of Electrical Charge	40
The Photoelectric Effect	41
The Compton Effect	41
Radioactivity	42
Rutherford and Atomic Structure	43
Bohr's Atomic Model	43
V. FROM THE OLD QUANTUM THEORY TO QUANTUM MECHANICS	46
Bohr's Atom and Energy Levels	46
Electron Diffraction and Wave–Particle Dualism	48
Schrödinger's Wave Mechanics	49
Schrödinger's Interpretation of Wave Mechanics	50

The Young Double Slit Experiment	52
Einstein's Objection to Born's Interpretation of Linear Superposition	54
Schrödinger's Cat Paradox	55
VI. QUANTUM MECHANICS: HEISENBERG'S MATRIX MECHANICS AND THE COPENHAGEN SCHOOL	57
Heisenberg's Philosophy	57
Matrix Mechanics	58
The Heisenberg Uncertainty Principle	60
The Subjectivity of Matter in the Copenhagen View	61
The Principle of Complementarity	62
Einstein's Photon Box Thought Experiment	63
The Einstein–Podolsky–Rosen Thought Experiment	64
Hidden Variables	66
VII. CONCEPTS OF THE THEORY OF RELATIVITY	68
The Principle of Relativity	68
Einstein's Discovery of the Theory of Relativity	70
The Spacetime Metric in Special Relativity	72
The Light Cone	73
Lorentz Transformations	73
Relative Simultaneity	74
Time Contraction and the Twin Paradox	75
The Fitzgerald–Lorentz Contraction	77
The Transformations of Velocities in Relativity Theory	77
VIII. FROM SPECIAL TO GENERAL RELATIVITY	79
The Paradoxes of Time Travel	79
The Energy–Mass Relation $E = mc^2$ in Special Relativity	81
The Meaning of $E = mc^2$	84
The Theory of General Relativity	84
The Metric of a Curved Spacetime	85

The Principle of Equivalence	86
The Tests of General Relativity	88
A Unified Field Theory	90
IX. THE UNIVERSE	93
Astrophysics	93
Black Holes	93
Pulsars	95
Dark Matter	96
Cosmology: The Physics of the Universe	97
The Early Friedman Model	100
The Hubble Law	101
The Beginning of the Universe	101
Olbers' Paradox	101
A Spiral Universe	103
The Separation of Matter and Antimatter in the Universe	104
X. CONFLICTS IN THE FOUNDATIONS OF THE QUANTUM AND RELATIVITY THEORIES	106
The Principle of Complementarity versus the Principle of Relativity	107
Atomism Versus Continuity	108
On Epistemology — Logical Positivism Versus Abstract Realism	109
Subjectivity Versus Objectivity	110
On Quantum Electrodynamics	113
Indeterminism Versus Determinism	114
REFERENCES AND NOTES	116
INDEX	123