

# Forces and Fields

The Concept of Action at a Distance  
in the History of Physics

Mary B. Hesse

DOVER PUBLICATIONS, INC.  
Mineola, New York

# Contents

I THE LOGICAL STATUS OF THEORIES	
Physics and epistemology	1
A realist view of theories	3
Operationalism	6
The hypothetico-deductive method and falsifiability	8
The dictionary theory	13
Models	21
II THE PRIMITIVE ANALOGIES	
Analogies in primitive scientific explanation	29
Nature as 'Thou': indefiniteness of the problem of interaction	34
The Pre-Socratics: distinction between matter and force	39
Atomism	42
Immaterial causes	46
III MECHANISM IN GREEK SCIENCE	
Mechanical analogies among the cosmologists and medical writers	51
The <i>horror vacui</i> and <i>antiperistasis</i>	54
Aristotle: matter and form and the primary qualities	60
Aristotle: theory of motion and change	63
Aristotle: the principle of action by contact	67
Aristotle: the unmoved first mover	70
IV THE GREEK INHERITANCE	
The primitive analogies in medieval belief	74
The emanation theories	77
Multiplication of species	79
The theory of vacuum-suction	82
Gilbert's <i>De Magnets</i>	86
Francis Bacon's classification of actions at a distance	91
V THE CORPUSCULAR PHILOSOPHY	
Falsifiability as a seventeenth-century criterion for theories	98
Descartes's mechanical continuum	102
Descartes's method	108
Corpuscular and medium theories	112
Locke on the mechanical philosophy	121
VI THE THEORY OF GRAVITATION	
Gravity as internal tendency or external attraction	126
The planetary orbits	129
An analysis of Newton's laws of motion	134
Universal gravitation as a mathematical law	144
Universal gravitation as a physical hypothesis	148
Newton's atomism and active principles	153

## VII ACTION AT A DISTANCE

Leibniz's attack on action at a distance	157
Philosophical justifications of action at a distance	163
Kant : <i>The Metaphysical Foundations of Natural Science</i>	170
Kant : infinite divisibility of matter as a regulative principle	173
Kant : attraction and repulsion	176
Elastic fluid theories in physics and chemistry	180

## VIII THE FIELD THEORIES

Euler's hydrodynamics	189
Criteria for continuous contact-action	195
Faraday : the physical nature of lines of force	198
Faraday : criteria for action at a distance	203
Maxwell : mechanical and field theories of continuous action	206
Hertz : interpretations of Maxwell's equations	212
The Continental action-at-a-distance school	216
Gravitation	222

## IX THE THEORY OF RELATIVITY

Interpretations of the Michelson-Morley experiment	226
Consequences of the Lorentz transformation	235
Milne's action-at-a-distance theory	239
Einstein's theory of gravitation	245
Conventional and factual aspects of geometry	253

## X MODERN PHYSICS

The empirical basis of quantum mechanics	259
The wave-particle duality and uncertainty principle	263
Sub-quantum theories	267
Modes of action in the quantum field	270
The meson and Maxwell fields	275
The action-at-a-distance theory of Wheeler and Feynman	279
Reversibility of cause and effect	285

## XI THE METAPHYSICAL FRAMEWORK OF PHYSICS

Some heuristic and metaphysical considerations	290
Theoretical aspects of extrasensory perception	295

## APPENDIX I

305

## APPENDIX II

306

## BIBLIOGRAPHY

308

## INDEX OF PROPER NAMES

313

## INDEX OF SUBJECTS

316