

Cambridge University Press

0521533295 - Innovation in Maxwell's Electromagnetic Theory: Molecular Vortices, Displacement Current, and Light - Daniel M. Siegel

Frontmatter/Prelims

[More information](#)

James Clerk Maxwell's equations for the electromagnetic field provide the basis for a good portion of twentieth-century science and technology. Two of Maxwell's contributions in this area – the displacement current and the electromagnetic theory of light – are among the most spectacular innovations in the history of physics, not only because of their immense impact but also because they constitute paradigmatic examples of theoretically motivated innovation, undertaken on the basis of little or no experimental evidence. Historians and philosophers of science have been drawn to this subject, but the technical complexities and thematic subtleties of Maxwell's work have turned out to be difficult to unravel, and scholarship to date has generated more questions than answers.

The key to an understanding of Maxwell's innovations, according to Daniel Siegel's analysis, has been visible all along, if unappreciated: Interspersed through Maxwell's work in electromagnetic theory are certain mechanical models of the electromagnetic field, which have commonly been regarded as amusing but irrelevant. It becomes clear, however, on the basis of a close analysis of the original texts – with careful attention to the equations as well as the words – that mechanical modeling played a crucial role in Maxwell's initial conceptualizations of the displacement current and the electromagnetic character of light. Dr. Siegel also locates Maxwell's work in the full sweep of nineteenth-century electromagnetic theory – from Oersted, Ampère, and Faraday through Hertz and Lorentz – and in the context of the methodological traditions and perspectives on the nascent physics discipline at the universities of Edinburgh and Cambridge.

Cambridge University Press

0521533295 - Innovation in Maxwell's Electromagnetic Theory: Molecular Vortices, Displacement Current, and Light - Daniel M. Siegel

Frontmatter/Prelims

[More information](#)

Innovation in Maxwell's electromagnetic theory

Cambridge University Press

0521533295 - Innovation in Maxwell's Electromagnetic Theory: Molecular Vortices, Displacement
Current, and Light - Daniel M. Siegel

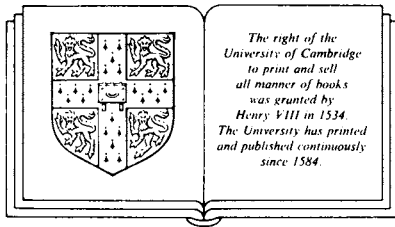
Frontmatter/Prelims

[More information](#)

Innovation in Maxwell's electromagnetic theory

Molecular vortices, displacement current,
and light

DANIEL M. SIEGEL
University of Wisconsin



CAMBRIDGE UNIVERSITY PRESS
Cambridge
New York Port Chester Melbourne Sydney

Cambridge University Press
0521533295 - Innovation in Maxwell's Electromagnetic Theory: Molecular Vortices, Displacement
Current, and Light - Daniel M. Siegel
Frontmatter/Prelims
[More information](#)

PUBLISHED BY THE PRESS SYNDICATE OF THE UNIVERSITY OF CAMBRIDGE
The Pitt Building, Trumpington Street, Cambridge, United Kingdom

CAMBRIDGE UNIVERSITY PRESS
The Edinburgh Building, Cambridge CB2 2RU, UK
40 West 20th Street, New York NY 10011-4211, USA
477 Williamstown Road, Port Melbourne, VIC 3207, Australia
Ruiz de Alarcón 13, 28014 Madrid, Spain
Dock House, The Waterfront, Cape Town 8001, South Africa

<http://www.cambridge.org>

© Cambridge University Press 1991

This book is in copyright. Subject to statutory exception
and to the provisions of relevant collective licensing agreements,
no reproduction of any part may take place without
the written permission of Cambridge University Press.

First published 1991
First paperback edition 2002

A catalogue record for this book is available from the British Library

Library of Congress Cataloguing-in-Publication Data
Siegel, Daniel M.
Innovation in Maxwell's electromagnetic theory : molecular
vortices, displacement current, and light / Daniel M. Siegel.
p. cm.
ISBN 0 521 35365 3 hardback
1. Electromagnetic theory. 2. Physics – History. I. Title.
QC670.S48 1991
530.1'41–dc20 90-42511
CIP

ISBN 0 521 35365 3 hardback
ISBN 0 521 53329 5 paperback

Cambridge University Press

0521533295 - Innovation in Maxwell's Electromagnetic Theory: Molecular Vortices, Displacement
Current, and Light - Daniel M. Siegel

Frontmatter/Prelims

[More information](#)

For the women in my life

Rebecca

Shulamith

Ruth

Rebecca, Deborah, Sarah

CONTENTS

| | | |
|--|-------------|-----------|
| <i>Preface</i> | <i>page</i> | <i>ix</i> |
| Introduction | | 1 |
| 1 The background to Maxwell's electromagnetic theory | | 5 |
| 2 Mechanical image and reality in Maxwell's electromagnetic theory | | 29 |
| 3 The elaboration of the molecular-vortex model | | 56 |
| 4 The introduction of the displacement current | | 85 |
| 5 The origin of the electromagnetic theory of light | | 120 |
| 6 Beyond molecular vortices | | 144 |
| Conclusion | | 168 |
| Appendix 1. Draft of "On Physical Lines of Force," a fragment | | 174 |
| Appendix 2. Drafts of "A Dynamical Theory of the Electromagnetic Field" | | 180 |
| Appendix 3. Vortex rotations in a curl-free region | | 182 |
| <i>Notes</i> | | 185 |
| <i>Index</i> | | 221 |

PREFACE

The historian of science cannot be unmindful of the fact that, for better or for worse, science, as practiced now and in the past, furnishes one of our central models of rational thought and judgment. Some would use history to demonstrate the worthiness of science as a model for rationality; others would use history to demonstrate the limitations of science in this respect. Above all, however, awareness of the paradigmatic role of science urges the historian of science to seriousness of purpose in trying to delineate and understand the practice of science in the past. In particular, I here endeavor to delineate and understand, in historical context, James Clerk Maxwell's seminal work in electromagnetic theory. Understanding of matters of any significance, however, seems never to come easily: This book has been long in gestation, and it makes some demands of its reader.

I was introduced to the historical study of Maxwell by Martin Klein, whose work and counsel have been seminal for me.

Jed Buchwald, Francis Everitt, Peter Harman, John Heilbron, Ole Knudsen, and David Wilson have furnished ideas, sources, and encouragement beyond what scholarly citations can acknowledge.

My work has been enriched by the conversation as well as the scholarly publications of Joan Bromberg, Geoffrey Cantor, Alan Chalmers, Michael Crowe, Gregory Good, John Hendry, Jonathan Hodge, Robert Kargon, Donald Moyer, Richard Olson, Paul Theerman, and Norton Wise. Interaction with other participants during the conference "Cambridge Mathematical Physics in the Nineteenth Century," held at Grasmere, England, in March 1984 – which resulted in the volume *Wranglers and Physicists*, edited by P. M. Harman (Manchester University Press, 1985) – opened new vistas.

My colleagues over the years in White Hall at the University of Wisconsin – William Coleman, Victor Hilts, David Lindberg, and

Preface

x

Robert Siegfried – have been supportive intellectually and personally. My students in recent seminars on Maxwell and on scientific method in the nineteenth century, including Michael Boersma and Derrick Mancini, have helped in the clarification of many issues.

Helen Wheeler and Cambridge University Press have given help and encouragement throughout the writing and publishing process.

The Cambridge University Library has been generous with assistance and permissions pertaining to Maxwell materials; I thank also the Edinburgh University Library for permission to quote from Balfour Stewart's notes on James D. Forbes's lectures.

The National Science Foundation and the Graduate School of the University of Wisconsin have been financially supportive.

Much of Chapter 2 appeared in *Wranglers and Physicists* and is used here with the permission of Manchester University Press; much of Chapter 4 appeared in *Historical Studies in the Physical and Biological Sciences*, 17 (1986), 99–146, and is used here with the permission of the University of California Press.