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ELECTRODYNAMICS OF MOVING MEDIA

Report of the National Research Council Committee on
Electrodynamics of Moving Media

By

W. F. G. Swann, John T. Tate, H. Bateman, E. H. Kennard

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ELECTRODYNAMICS OF MOVING MEDIA

Report of the National Research Council Committee on Electro-
dynamics of Moving Media*

PART I

By W. F. G. SWANN
Professor of Physics, University of Minnesota

PART II

By JOHN T. TATE
Professor of Physics, University of Minnesota

PART III

By H. BATEMAN
Professor of Mathematics, California Institute of Technology

PART IV

By E. H. KENNARD
Professor of Mathematics, Cornell University

*This committee of the Division of Physical Sciences of the National Research Council consists of the following members: J. S. Ames, Professor of Physics, and Director, Physical Laboratory, Johns Hopkins University, Chairman; S. J. Barnett, H. Bateman, E. H. Kennard, C. M. Sparrow, W. F. G. Swann, J. T. Tate.

CONTENTS

	Page
Part I—THE FUNDAMENTALS OF ELECTRODYNAMICS . . .	5
Introduction	5
Electrostatics	6
The laws of inverse squares and of conservation of charge	6
Case where electric field is the quantity fundamentally defined	8
Dielectrics	10
Steady currents in continuous circuits	12
Varying currents in closed circuits	15
Dynamical systems	15
The general equations	21
The significance of the equations and of the quantities occurring in them	23
Foundation of electrodynamic laws in relation to actual observation	27
Redefinition of the field vectors	29
The value of the field vectors	29
The degree of fundamentality of the circuital relations	32
The force equation in relation to electrons	33
The equations of conservation of momentum and energy	35
Significance of the equations	35
Localization of energy	36
The momentum equation	38
The energy equation	40
The Lorentzian electron and the conservation of energy	41
Material media	44
The Lorentzian equations	44
A derivation of the Lorentzian equations for moving media	47
Appendix	55
Note 1. Concerning definitions in terms of a unit pole or unit magnet	55
Note 2. Equations for free aether	56
Equations for media containing charges	56
Note 3. Concerning the significance of ϵ in the circuital relations	61
Note 4. Concerning definitions in terms of the motion of an electron	66
The ultimate form assumed by the circuital relations	67
Relations between the above definition of H and that ordinarily employed	68
Note 5. The role played by definition and by the force equation in relation to the invariance of the circuital relations under the transformation of the restricted theory of relativity	68
Case where E and H are not defined in terms of the motion of an electron	71
Note 6. Calculation of the term $\iiint \Delta \sigma \left(E_1 + \frac{v \cdot H_1}{C} \right) \rho d\tau$	72
Note 7	74
Part II—UNIPOLAR INDUCTION	75
Introduction	75
Electrodynamical theory of unipolar induction	76
Fundamentals	76
The basic problem of unipolar induction	77
Unipolar induction experiments	85
Experiments with closed circuits	85
Electrostatic experiments	88
Status of the moving line theory	92
Summary	95

Part III—EQUATIONS FOR THE DESCRIPTION OF ELECTROMAGNETIC PHENOMENA.....	96
Introductory remarks on electricity, space and time.....	96
Theory of the Lorentz-Fitzgerald contraction.....	99
The structure of matter.....	102
The field of a moving electric pole.....	105
The reflection of light at a moving plane mirror.....	108
Behaviour of electrical quantities under a relativity transformation.....	112
Fields with singularities of a complex nature which move with velocities less than c	114
Field equations for a moving dielectric.....	123
Constitutive relations.....	126
Fields with singularities that move along straight lines with velocity c	138
Dynamical equations of motion.....	154
BIBLIOGRAPHY AND NOTES.....	158
Part IV—THE TROUTON-NOBLE EXPERIMENT.....	162
Symbols.....	162
The genesis of the experiment.....	162
The experiment.....	163
Description.....	163
Critique.....	163
Theory of a moving condenser.....	164
Maxwell-Lorentz theory.....	165
Condenser with ether as dielectric; β small.....	166
Effect of a material dielectric of unit permeability.....	168
Local torque in a dielectric.....	169
The effect of mica in Trouton and Noble's condenser.....	171
The fine-structure of the charge on the plates.....	171
The explanation by relativity.....	171
Other ways of escape.....	172
In conclusion.....	172

PART I
THE FUNDAMENTALS OF ELECTRODYNAMICS

BY W. F. G. SWANN

INTRODUCTION

The present report purposes to make a critical survey of some of the more familiar aspects of the subject with a view of inquiring as to what parts may be considered as relying upon experiment, or upon deduction from fundamental principles, and what parts are mere definition or scaffolding, convenient for the correlation of the experimental laws but in no sense calling for experimental proof themselves. Any individual experiment usually covers a very limited region of the whole field of investigation of which it forms a part. It is a representative of a much larger class, from which it is chosen on the grounds of practicability. In citing an experimental foundation in any particular case we shall not therefore confine ourselves to individual experiments which have been performed, but shall speak rather of general classes of experiment of which any particular experiment will form a special case.

One method of procedure would be to take the complete scheme of equations as formulated by Lorentz, and discuss everything in terms of these. To do this, however, would be to clothe the subject with considerable artificiality as regards certain important fields of its application. The attitude which one adopts toward the subject, his way of thinking about it, even the method of expression of its laws is to some extent bound up with the degree of generality which he has in mind for its application. Thus, for example, there is a perfectly consistent scheme of hypotheses applicable to the case where one confines himself to unvarying currents in closed wire circuits; and while this subject may be treated as part of the general case of electronic motion, it may as far as its own requirements are concerned, be discussed in different and somewhat simpler language. The field of application of this special case is moreover so great that it constitutes as it were a little subject in itself, and it is therefore convenient to discuss what would be its laws from the standpoint of one who never had occasion to deal with more general cases. Following out this plan, we shall consider the whole subject in four stages applicable respectively to the following cases.

1. Electrostatics.
2. Steady currents in closed circuits.
3. Varying currents in closed circuits.
4. The general case as symbolized by the Lorentzian equations for free aether and their adaptation to a material medium.

Certain matters of detail will be relegated to notes in an appendix to this report.

ELECTROSTATICS

The laws of inverse squares and of conservation of charge.—The fundamental law is here, of course, the law of inverse squares; but, the meaning of this law is to some extent a function of the light in which we regard it. We may speak of it in terms of the law of force between certain material bodies, and we may in fact formulate the general law in the following way:

Let there be given an assemblage of bodies. Then it is possible to assign to each element of volume of the bodies a definite number ρ such that on writing down vectors

$$\rho \rho' dr_1 dr_2 / 4\pi r^2$$

for the forces between each pair of corresponding elements, the forces so obtained when compounded will give the resultant mechanical forces and couples exerted by the bodies on each other. } A

Moreover, if the bodies be moved to new positions, a similar result holds, and the values of $\int \rho dr$ for any one of the bodies in the two positions are equal. }

Surface distributions may, of course, be included as limiting cases of volume distributions.

This is the law which may be regarded as the experimental basis of electrostatics. In this form the definition of charge density is not made until the law has been recognized, and indeed until then it has no meaning. The superposability of effects, the proportionality of mechanical force to charge, and the conservation of charge are contained in the statement of the law, once the experimental fact has been assumed.

A consideration of the matter will show that all electrostatic experiments designed to test the law of inverse squares are particular cases of a general experiment of this type. An experiment with Coulomb's torsion balance is of course of this type; and while the statement may not be obvious at first sight, a little consideration will show that even experiments having to do with the absence of field inside a hollow conductor are of this form. Thus in its most general form this experiment with the hollow conductor may be taken to show that a charged body placed inside such a shield experiences no mechanical force as a result of the presence of charges outside. Now it is a mathematical fact that whatever distribution ρ be assigned to the space outside of a surface, it is always possible to assign a function σ varying over the surface in such a way that while $\int \sigma dS = 0$, the vectorial sum of

$$\iiint \frac{\rho dr}{r^3} \quad \text{and} \quad \iint \frac{\sigma dS}{r^2}$$

is zero for any point which is inside the surface, and whose distances from the various volume elements dr and surface element dS are given by the corresponding values of r . It follows that if the mechanical force upon a body is given by a law of the type above specified, it is certainly