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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

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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
>
> $$\rho_1\rho_2 d\tau_1 d\tau_2/4\pi r^2$$
>
> 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.
>
> Moreover, if the bodies be moved to new positions, a similar result holds, and the values of $\int\rho d\tau$ for any one of the bodies in the two positions are equal. } A

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

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

is zero for any point which is inside the surface, and whose distances from the various volume elements $d\tau$ 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