Electrodynamics of Moving Media

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(Z. Naturforsch. **32 a**, 823—828 [1977]; received May 10, 1977)

On the basis of the Minkowski formulation, the total energy-momentum tensor of a system consisting of matter and electromagnetic fields is derived from the macroscopic theory. The analysis of this tensor shows that the electromagnetic fields supply the matter with momentum and energy. Consequently, the electromagnetic part and the material part overlap each other in the total energy-momentum tensor. Hence it is impossible to divide the total energy-momentum tensor into an electromagnetic tensor and a material tensor.

In a closed system, in general, only the total energy-momentum tensor has physical significance and can be defined.

Further, the generalized force which acts on the matter is obtained and interpreted clearly.

I. Introduction

Electrodynamics of moving media has been discussed by a large number of investigators for long years, and until the present many different forms of an electromagnetic energy-momentum tensor within media have been put forward [1–4]. However, no form is universally accepted, although Minkowski's tensor is the most well-known and widely used of them [5].

The present paper develops Møller's theory of an elastic body [6] and analyzes, on the basis of the Minkowski formulation, a system consisting of matter and electromagnetic fields. The effect of the electromagnetic fields on the matter is revealed. Further, the generalized force which acts on the matter is obtained and interpreted clearly.

For the sake of simplicity, only isotropic and nondispersive media with linear constitutive relations are considered. Further, the summation convention is used. The Latin subscripts assume the values 1, 2, 3, 4, whereas the Greek subscripts assume the values 1, 2, 3.

II. The Lorentz Force, the Joule Heat, and the Electrostriction and Magnetostriction Forces

In the first place, the force per unit volume that acts on stationary media in stationary electromagnetic fields is considered. If the elastic force is left out of consideration, it is given by [7, 8]

$$\boldsymbol{f}_{\text{stat}} = \varrho \boldsymbol{E} + \boldsymbol{J} \times \boldsymbol{B} - \tfrac{1}{2} E^2 \operatorname{grad} \varepsilon - \tfrac{1}{2} H^2 \operatorname{grad} \mu + \operatorname{div} {}^2\sigma \,, \qquad (1)$$

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where ϱ and $\boldsymbol{J}$ are the true charge and current densities. The last term in (1) is the vector whose components are

$$(\operatorname{div} {}^2\sigma)_\alpha = \partial \sigma_{\alpha\beta} / \partial x_\beta \,, \qquad (2)$$

where

$$\sigma_{\alpha\beta} = -\tfrac{1}{2} a_1 E_\alpha E_\beta - \tfrac{1}{2} a_2 E^2 \delta_{\alpha\beta} - \tfrac{1}{2} b_1 H_\alpha H_\beta - \tfrac{1}{2} b_2 H^2 \delta_{\alpha\beta} \,; \qquad (3)$$

the Kronecker symbol is denoted by $\delta_{\alpha\beta}$. The coefficients a_1 and a_2 in (3) represent the rate of change due to the strains of the permittivity ε of the medium, whereas b_1 and b_2 represent that of the permeability μ.

Note that the last term in (1) is quite different from the other terms in nature. It represents the electrostriction and magnetostriction forces; these act as surface forces, because $\sigma_{\alpha\beta}$ represents the internal stresses which occur to evoke the strains. In contrast with it, the first four terms in (1) represent the Lorentz force, which acts as a volume force.

Even in the general case of time-dependent fields, only the Lorentz force and the electrostriction and magnetostriction forces act immediately on the medium. Moreover if the fields do not vary rapidly, it may be assumed that the Lorentz force and the electrostriction and magnetostriction forces are represented by (1). The generalized force is discussed in detail in Section VI.

Next the case in which media are moving with a constant velocity $\boldsymbol{v}$ is considered. The following identity is generated from Minkowski's field equations by the tensor manipulation [9]:

$$f_i^* = -\partial S_{ik} / \partial x_k \,, \qquad (4)$$

where

$$f_i^* = F_{ij} J_j + \frac{1}{4} \left(F_{kl} \frac{\partial H_{kl}}{\partial x_i} - \frac{\partial F_{kl}}{\partial x_i} H_{kl} \right), \qquad (5)$$

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National Research Council (U.S.). Committee on electrodynamics of moving media,William Francis Gray Swann,John Torrence Tate,Harry Bateman

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Electrodynamics of Moving Media National Research Council (U.S.). Committee on electrodynamics of moving media,William Francis Gray Swann,John Torrence Tate,Harry Bateman,1922 *Models of Particles and Moving Media* Donald Dunn,2012-12-02 Models of Particles and Moving Media deals with the use of mathematical models to study electrical interactions with moving particles and moving media Topics covered range from space time and the Galilean transformation to the Lorentz transformation of time and space and of Maxwell s equations Forces and wave interaction with uniformly moving circuits and continua are also considered along with non uniform motion of charged particles in prescribed electric and magnetic fields Comprised of seven chapters this book begins with an overview of some of the ways in which motion can be described with particular reference to the concept of space time and the Galilean transformation The discussion then turns to the Lorentz transformation of time and space giving emphasis on the transformation of coordinates time dilation and the Lorentz contraction and conservation of mass and energy After an analysis of the Lorentz transformation of Maxwell s equations forces and wave interaction with uniformly moving circuits and continua are reviewed along with non uniform motion of charged particles in prescribed electric and magnetic fields The book concludes by describing the use of the Lagrangian model and the Eulerian model to determine the motion of many interacting particles and the motion of charged and conducting fluids respectively This monograph is written primarily for students and researchers in the fields of mathematics and physics **Electrodynamics of Moving Media** National Research Council (U.S.). Committee on electrodynamics of moving media,William Francis Gray Swann,John Torrence Tate,Harry Bateman,1922

ELECTROMAGNETISM IN MOVING, CONDUCTING MEDIA. RUDOLPH MORTON KALAFUS,1966

Electrodynamics of Moving Media Luiz Valente Boffi,1957 **Electrodynamics of Solids and Microwave Superconductivity** Shu-Ang Zhou,1999-07-23 Die Elektrodynamik von Festk rpern ist ein interdisziplin r angelegtes Thema zu dem elektromagnetische Ph nomene mechanische Bewegungen und Verformungen sowie W rmeleitungen in festen Stoffen gleicherma en beitragen Dieses einf hrende und dennoch umfassende Lehrbuch zur Theorie der Elektrodynamik und Halbleitertechnik richtet sich an Physiker ebenso wie an Elektrotechniker Maschinenbauer und Studenten der einschl gigen Fachrichtungen 08 99 Electrodynamics Masud Chaichian,Ioan Merches,Daniel Radu,Anca Tureanu,2016-10-31 This book is devoted to the fundamentals of classical electrodynamics one of the most beautiful and productive theories in physics A general survey on the applicability of physical theories shows that only few theories can be compared to electrodynamics Essentially all electric and electronic devices used around the world are based on the theory of electromagnetism It was Maxwell who created for the first time a unified description of the electric and magnetic phenomena in his electromagnetic field theory Remarkably Maxwell s theory contained in itself also the relativistic invariance of the special relativity a fact which was discovered only a few decades later The present book is an outcome of the authors teaching experience over many

years in different countries and for different students studying diverse fields of physics The book is intended for students at the level of undergraduate and graduate studies in physics astronomy engineering applied mathematics and for researchers working in related subjects We hope that the reader will not only acquire knowledge but will also grasp the beauty of theoretical physics A set of about 130 solved and proposed problems shall help to attain this aim **Scientific and Technical Aerospace Reports** ,1969 Lists citations with abstracts for aerospace related reports obtained from world wide sources and announces documents that have recently been entered into the NASA Scientific and Technical Information Database **Electrodynamics of Moving Media** National Research Council (U S) Commit,2018-10-11 This work has been selected by scholars as being culturally important and is part of the knowledge base of civilization as we know it This work is in the public domain in the United States of America and possibly other nations Within the United States you may freely copy and distribute this work as no entity individual or corporate has a copyright on the body of the work Scholars believe and we concur that this work is important enough to be preserved reproduced and made generally available to the public To ensure a quality reading experience this work has been proofread and republished using a format that seamlessly blends the original graphical elements with text in an easy to read typeface We appreciate your support of the preservation process and thank you for being an important part of keeping this knowledge alive and relevant Remote Sensing of Turbulence Victor Raizer,2021-10-03 This book offers a unique multidisciplinary integration of the physics of turbulence and remote sensing technology Remote Sensing of Turbulence provides a new vision on the research of turbulence and summarizes the current and future challenges of monitoring turbulence remotely The book emphasizes sophisticated geophysical applications detection and recognition of complex turbulent flows in oceans and the atmosphere Through several techniques based on microwave and optical IR observations the text explores the technological capabilities and tools for the detection of turbulence their signatures and variability FEATURES Covers the fundamental aspects of turbulence problems with a broad geophysical scope for a wide audience of readers Provides a complete description of remote sensing capabilities for observing turbulence in the earth s environment Establishes the state of the art remote sensing techniques and methods of data analysis for turbulence detection Investigates and evaluates turbulence detection signatures their properties and variability Provides cutting edge remote sensing applications for space based monitoring and forecasts of turbulence in oceans and the atmosphere This book is a great resource for applied physicists the professional remote sensing community ecologists geophysicists and earth scientists **NASA Scientific and Technical Reports** United States. National Aeronautics and Space Administration Scientific and Technical Information Division,1965 *A Selected Listing of NASA Scientific and Technical Reports for ...* United States. National Aeronautics and Space Administration. Scientific and Technical Information Division,1964 *NASA Technical Translation* ,1966 **Analytic Number Theory, Modular Forms and q-Hypergeometric Series** George E. Andrews,Frank Garvan,2018-02-01 Gathered from the 2016 Gainesville Number

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