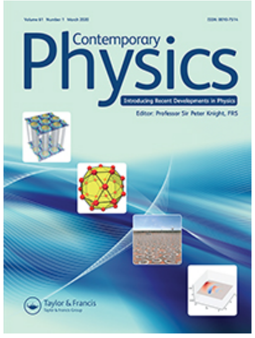

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Tensor-valued random fields for continuum physics, 1st edition

by Anatoliy Malyarenko and Martin Ostoja-Starzewksi, Cambridge Monographs on Mathematical Physics, Cambridge, Cambridge University Press, 2019, 310 pp., $145 USD (hardback), ISBN 978-1-108-42985-6. Scope: monograph. Level: postgraduate, specialist.

John D. Clayton

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communication along with contemporary developments. It explains comprehensively about the generation, amplification, and detection of the optical signals. Moreover, this book offers intellectual nourishment for the researchers in other areas of physics and electronics where photonic devices, information theory, and communication systems are studied. This book is ideal for advanced undergraduate, postgraduate students, and professionals who want to pursue their career in the field of optical communication and photonics-based industries. However, I would like to suggest that in addition to the end problems, authors should add the examples or practice problems inside chapters for better understanding and longevity of the concepts. The book, authored by Papen and Blahut, provides an updated literature on signals and systems and communication systems in the optical regime. The list of references at the end of each chapter provides a unique collection which helps the readers to further explore. The authors have offered a rigorous mathematical analysis of fibre optics as a linear and nonlinear channel for communication, interference of optical signals in the channels using both classical and modern/quantum optics perspectives.

In preface, the authors stated as: 'we believe that some readers who are not interested in guided lightwave communications will find value added to the understanding of conventional topics of digital communication. This book is addressed to them as well'. I can say that readers can understand concepts of information theory, analogue, and digital communication in detail along with the advanced optical communication. Overall, the book is well organised and deserves to be considered as the textbook for the subjects of photonic signals and systems and optical communication in the curriculum of telecommunication engineering.

Muhammad Mahmood Ali
Department of Electronic and Computer Engineering
University of Limerick, Limerick, Ireland
dr.mahmoodnaz@gmail.com
http://orcid.org/0000-0001-8236-2459

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Tensor-valued random fields for continuum physics, 1st edition, by Anatoliy Malyarenko and Martin Ostoja-Starzewksi, Cambridge Monographs on Mathematical Physics, Cambridge, Cambridge University Press, 2019, 310 pp., $145 USD (hardback), ISBN 978-1-108-42985-6. Scope: monograph. Level: postgraduate, specialist.

Tensor-valued random fields for continuum physics is a meticulously written book with a firm theoretical basis in mathematics, physics, and engineering mechanics. This book covers a number of general and specialised topics in random field variables applied to physical problems in primarily a continuum, as opposed to discrete, setting. Continuum physics here encompasses solid mechanics – elasticity, thermo-elasticity, visco-elasticity, plasticity, damage mechanics – fluid mechanics, heat conduction, and electromagnetism, among other specialised topics. Most tensor-valued fields appearing in theoretical models of these phenomena are categorised by the authors into two categories: dependent or primary field quantities such as displacement, velocity, strain, and stress that are universal to each discipline; and constitutive quantities such as stiffness, conductivity, or permeability that are peculiar to certain substances or classes of substances. These quantities take values in linear spaces of first or higher rank and generally are of random character, that is, they display spatially inhomogeneous, scattered behaviours. This observation provides impetus for the book as noted in the Introduction: the relatively well-developed theory of scalar random fields (rank 0) should be generalised to tensor random fields (TRFs) of ranks 1 and higher.

The stated purpose of this book to provide a rigorous mathematical treatment of TRFs that can be readily applied to problems in continuum physics. The main mathematical problem solved by the authors in the text is stated on page 7: 'We [the authors] would like to find the general form of the one-point and two-point correlation tensors of a homogeneous and isotropic tensor-valued random field $T(\mathrm{A})$ as well as the spectral expansion of the above field'. Obvious applications include spatially random material microstructures, turbulent Navier-Stokes fluids, and stochastic wave propagation, both acoustic and electromagnetic. In many cases, randomness appears at a higher length scale due to anisotropy inherent in a finer-scale response, for example, the ubiquitous solid mechanics problem of homogenisation of a domain consisting of an aggregate of single crystals analysed by Voigt, Hill, and countless others. Besides the introductory material, most of the content is focused on intricate derivations of correlation functions and special properties of TRFs of ranks 1 through 4. Speculative applications for classical elastic and micro-polar continua, stochastic partial differential equations, and stochastic damage phenomena follow later. Much of the scope builds upon prior fundamental research and decades of experience by the authors who occupy scholarly positions in highly reputable academic institutions: A. Malyarenko is a Professor of Mathematics at Mälardalen University (Sweden); M. Ostoja-Starzewski is a Professor of Mechanical Science at the University of Illinois (USA), Institute for Condensed Matter Theory and Beckman Institute. The authors hold exceptional and prolific publication records in this research field. Nearly all of the content is theoretical, with the exception of a few numerical examples from computer simulations; experimental methods are not really addressed.

This book is a very dense volume of moderate length, 302 pages and front matter. The presentation is logical and systematic. The physical motivation for the work is given first, in the introductory chapter (not formally numbered) that defines TRFs conceptually and mathematically, presents some example governing equations from continuum physics where TRFs appear, and then lays out the general procedure to solve the main objective problem mentioned already (p. 8): 'We describe the set of homogeneous random fields and reject those that are not isotropic'.

After this introduction, the main part of the book contains four chapters. Chapter 1 provides scientific background on a broad spectrum of continuum physical theories wherein spatial randomness and local anisotropy coexist. Four different sources of the stochastic nature of field theory are listed: randomness of the operator in the governing equation, randomness of the forcing function, randomness of boundary or initial conditions, and (apparent) randomness of the primary field variable itself. Equations of continuum mechanics are listed, with a predilection towards a potential-based theory of dissipative thermo-mechanics with internal variables. Conductivity and elasticity theory are briefly reviewed. The stochastic dissipation function is discussed. Then multi-field theories are tersely summarised: thermo-elasticity and visco-elasticity (parabolic and hyperbolic forms), piezoelectricity, and damage mechanics of solids with random micro-crack fields. Generalised continuum mechanical theories are then mentioned in brief, including micro-polar elasticity and fully non-local models of the integral type. In each case, general forms of governing equations enabling random fields are maintained, for example, material coefficients are not presumed constant.

Chapter 2 reviews the advanced mathematical tools required for subsequent analysis of TRFs. Special topics from linear algebra, tensor calculus, geometry, topology, and group theory are covered. Theorems and examples abound many procured from other reputable sources in mathematics and mathematical physics. Symmetry operations, invariant theory, and special mathematical functions are of high prominence. The authors note how the MATLAB symbolic math toolbox is used to analyse symmetric covariant tensors and reduction equations. The same software is used often later to obtain intricate algebraic results on correlations in TRFs.

Chapter 3 provides the exact statement of the mathematical problem and its formal solutions, thereby comprising the most important and original content of this book. General forms of the one-point and two-point correlation tensors of a homogeneous and isotropic tensor-valued random field are found for tensors of ranks 0, 1, 2, 3, and 4. Different classes of fields are analysed for each rank, and many special cases are considered. Dozens of theorems are laid out systematically. Results are displayed through in-line equations, where functions or functionals entering such equations most often are collected in tabular form, generated using MATLAB symbolic manipulation. The intricate results tables themselves are impressive, if not spectacular, in appearance and complexity, cf. Fig. 3.10 which alone spans seven pages! This demonstrates the very careful work and intensity of effort put forth by the authors.

With the mathematical results firmly entrenched, applications of TRFs in continuum theories are revisited in Chapter 4. Topics covered include simulations of isotropic and homogeneous TRFs, ergodic TRFs, and interpretations of properties of TRFs in the context of continuum mechanics: kinematics and symmetric stresses in classical continua, asymmetric stresses in micro-polar continua. Interesting applications for composite microstructures then follow, including a useful hierarchy of meso-scale bounds on stiffness and compliance for a statistical volume element (SVE), and scaling functions for uncorrelated and correlated microstructures. A final unique application concerns fractal planetary rings and a stochastic model of their kinematics motivated by modern photographs of Saturn's rings. Chapter 4 concludes with propositions for future work: quasi-isotropic TRFs, acoustic tensors, and variograms.

Topics are covered in each main chapter with abundant mathematical rigor, fulfilling the overall objective. A few limitations are noted, however. The treatment of geometry and manifolds is directed towards support of group-theoretic categorisation and analysis of TRFs, which is quite sufficient for the applications that follow in the setting of linear mechanics. However, differential-geometric aspects of the field theories of mechanics, for example nonlinear kinematics and nonlinear elasticity theory on manifolds [1,2], are not mentioned. Some of the governing equations of mechanics analysed in the text and examples are nonlinear, but most constitutive models presume small stretch and small rotation and quadratic free energy functions, for example. Fully nonlinear elasticity theory as treated in [3] is outside the scope of the work, including detailed nonlinear constitutive theories of crystalline thermo-elasticity, plasticity, and piezoelectricity as developed in other prominent literature [4,5]. This reader appreciates, however, that many results in this book could apparently be generalised to fully nonlinear continuum mechanical models without excessive additional effort. Though an implied objective of the book is a demonstration towards physical problems in continuum physics, Chapter 4 reads as highly theoretical and speculative. The full utility and power of the theoretical developments of Chapter 3 therefore seem to await future work on the subject directed towards more concrete physical examples.

The apparent audience of this book is advanced graduate students and researchers in applied mathematics and mathematical physics. The subject matter proven in Chapter 3 on TRFs of ranks 1 through 4, in particular, is comprehensive and profound. Besides its documentation of these important theoretical results, the book serves as a highly useful and systematic reference work for advanced practitioners of stochastic continuum mechanics.

The book is mostly self-contained. However, many topical descriptions may be too brief for students and researchers without extensive prior training, for example, knowledge up to the level of a second-year graduate student in continuum mechanics, elasticity theory, linear algebra, and group theory. The book contains numerous definitions, proofs, and other dense mathematical descriptions. A few problems are worked through in the book to complement derivations, but no formal problem sets found in university course textbooks are given. The book is thus more suitable as a research reference than a formal textbook for graduate-level instruction.

The book concludes with a bibliography of over several hundred references, about 10 pages in length. Though not exceptionally long, this reference list is sufficient to support main topics in corresponding chapters. More thorough works on specific topics – including applications of this and related mathematical theory to particular mechanics and physics problems solved by the authors – adequately supplement the text. The authors credit particular works for origins of theories or mathematical results first derived elsewhere as deemed appropriate, either in the bibliography or in supplementary remarks that conclude the main chapters.

The quality of the editing, printing, and binding are superb, in accordance with the usual high standards of Cambridge University Press. The book contains grayscale and line figures that accompany examples cited in the text. These are all rendered with precision and quality, complementing the careful derivations throughout the book. Equations are superbly formatted, and the font sizes are appropriate, for example with subscripts and superscripts large enough to be clearly legible throughout. The aforementioned beautiful formatting of tables containing intricate mathematical expressions is particularly noteworthy. The book contains a detailed Table of Contents and a brief but sufficient subject index of around five pages. No author index, glossary, nor list of symbols is included. Though not essential, the latter would have been particularly helpful to the reader, given the abundant sophisticated notation.

Overall, the unique book *Tensor-valued random fields for continuum physics* is highly recommended as a research tool for scholars involved in contemporary analysis of stochastic continuum physics. Valuable techniques are gleaned from the book's sequential derivations and re-evaluations of governing equations in the rather unique context of tensor-valued random fields, a topic which has not heretofore been studied with the depth and rigor directed most often prior toward (much less daunting) scalar-valued fields. This book may very well become a classic, as it appears to be the first comprehensive mathematical treatment of tensor-valued random fields with physical applications.

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John D. Clayton
US ARL and University of Maryland, College Park, MD, USA
jdclayt1@umd.edu, jdclayt1@verizon.net

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Introduction to electricity and magnetism, by J. D. Walecka, Singapore, World Scientific, 2018, 272 pp., £75 (hardback), ISBN: 9789813272064, Scope: review. Level: undergraduate. Specialist.

The description 'Introduction to ... ' in a book title often covers a multitude of interpretations of the word 'introduction'. Here Walecka has indeed produced a text worthy of the description. That is not to say that the material does not reach a level suitable for undergraduate study, and quite quickly, but the pace and development is, in my opinion, judged well for first and second year undergraduates. I would guess that the text has been developed from a set of lecture notes as many of the observations, and conclusions are in a bullet-point format. I could imagine that some less experienced readers would appreciate slightly fuller explanations. Having said that, such an approach keeps the book concise.

I was provided with a hardback version of the book, which is a sturdy volume, and easy to use. The content is broken down, as one might expect, into three parts, electricity, magnetism, and electromagnetism. Electricity starts with simple electrostatics, working through Gauss' Law to potential and energy. Having reached capacitance Walecka treats DC circuits by considering Ohm's Law and Kirchoff's rules.

He takes a similar approach in the second part. Starting from a brief refresher on vectors, each of the fundamental Laws is brought in, such as Gauss', Biot-Savart, and Ampere's Law. These are topped off with a consideration of the Lorentz force and the usual applications of velocity selection, and mass spectrometry. This part concludes with a consideration of induction and magnetic materials, with induction leading to an introduction to AC theory in time-dependent circuits.

The last part brings all this together and considers electromagnetism as a whole with Maxwell's equations and electromagnetic waves. It finishes with the behaviour of electromagnetic waves in different inertial frames using Special Relativity.

I enjoyed the approach and the order of material. However, to be frank, several things irritated me while I was reading. What I noticed first was the diagrams, which are all line drawings with some greyscale shading. Although in the majority of cases these are perfectly clear, the fonts are inconsistent and italics are not used where they should be. The care exercised on the production of these is not uniform, and I feel the text is generally let down by them.