Lecture Notes in Physics

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Time-Harmonic Electromagnetic Fields in Chiral Media

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Frontispiece: Maori drawing of a spiral facial tattoo [After R. Huber, *Treasury of Fantastic and Mythological Treasures*, New York: Dover (1981)]

PREFACE

With ongoing progress in the construction of artificial composites, chiral materials will assume great importance. Such materials occur in nature as optically active molecules which display circular birefringence at optical frequencies. Since chirality is a geometric concept, it is conceivable that artificially chiral composites can be made to display circular birefringence even at lower, perhaps microwave, frequencies.

These lecture notes have been prepared to initiate practitioners of electromagnetic theory into the arcana of chiral media. The notes are intended to cover twenty class periods, and have been accordingly arranged. Though Sections 1 through 19 focus exclusively on electromagnetic fields, an extension of these concepts to acoustic waves is given in Section 20 in order to emphasize that it is geometry which gives rise to chirality. An $\exp[-i\omega t]$ harmonic time dependence is implicit throughout this work; only in Section 6 will time-dependent fields be considered. Familiarity with basic electromagnetic theory at the graduate level is assumed, and some experience with dyadic algebra will be useful but not necessary. As such, these notes are suitable for advanced graduate students as well as for researchers with background in electromagnetic theory. We trust that these notes will inspire a considerable number of researchers to be as fascinated by chiral media as we are.

A note on the notation used here: Generally, new notation has been explained upon introduction. An $\exp[-i\omega t]$ harmonic time dependence is implicit throughout, the sole exception being in Section 6. Boldface letters have been used to denote vectors, while German letters denote dyadics. The symbols $\{\mathbf{E}, \mathbf{H}, \mathbf{D}, \mathbf{B}\}$ have been used consistently to denote complex-valued field amplitudes; in the first part of Section 6, however, these symbols denote complex instantaneous fields. The symbol σ has been used as a wavenumber in defining wavefunctions, such as $\mathbf{M}_n^{(1)}(\sigma\mathbf{r})$ and $\mathbf{N}_n^{(1)}(\sigma\mathbf{r})$ of Section 10, as well as the scalar Green's function $g(\sigma:R) = \exp[i\sigma R]/R$. The wavenumbers in an isotropic chiral medium are denoted by γ_1 for the left-circularly polarized fields, and by γ_2 for the right-circularly polarized fields; it is to be emphasized here that $k = \omega(\epsilon\mu)^{1/2}$ is not a wavenumber in a chiral medium. Throughout this work, it has been assumed that the chiral media are homogeneous as well as at rest. Special notation has been used for acoustically chiral solids in Section 20, wherein it has been explained as necessary.

We wish to record our gratitude to our colleague Professor Richard P. McNitt, who went through the draft manuscript very carefully. Any residual errors are due to us, and no responsibility resides with him!

Comments on the original manuscript provided by Professor Jürgen Ehlers, an editor of the Lecture Notes in Physics Series, resulted in considerable improvements and are greatly appreciated.

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We also acknowledge the patience of our family members, and dedicate this work to a glorious future for all the children of the world.

University Park,
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March 1989

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