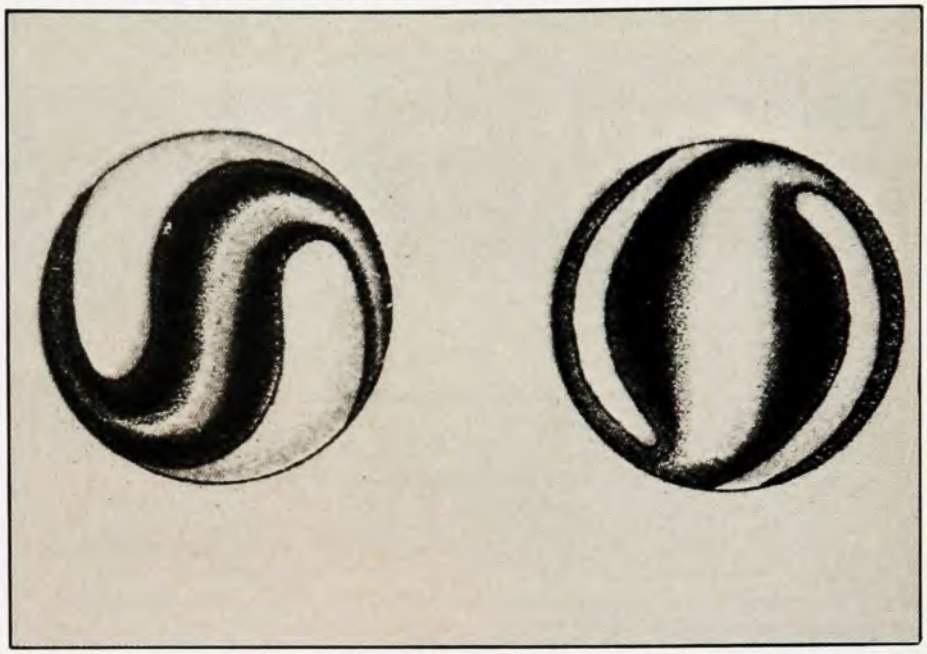
The beautiful and mysterious behavior of liquid crystals

Liquid Crystals

S. Chandrasekhar
342 pp. Cambridge U.P., New York, 1977.
$38.50

Reviewed by J. David Litster



A droplet of cholesteric liquid crystal heated from below shows an often violent rotation of the optic axis. These sketches are from a paper by Otto Lehmann [Ann. Physik **4**, 649 (1900)] where the phenomenon was first reported. A theoretical explanation due to Frank M. Leslie is presented in chapter four of Sivaramakrishna Chandrasekhar's *Liquid Crystals*, reviewed here.

Liquid crystals exist in some of the most esthetically interesting states of condensed matter; they exhibit beautiful and often mysterious optical behavior. An example is the thermally induced rotation of the optic axis in cholesteric materials that was first observed by Otto Lehmann in 1900 (see the accompanying illustration). Since Lehmann, scientific interest in liquid crystals has waxed and waned several times.

The most recent wave of activity began about ten years ago with both potential applications and fundamental scientific interest as driving forces. While it seems unlikely that liquid crystals will provide the perfect passive electro-optic display, their low power consumption has enabled them to capture a substantial fraction of the market for calculators and wrist watches. The rich varieties of liquid crystalline order that exist, especially the various smectic phases, are exciting to those interested in basic condensed-matter physics. These phases provide a challenge to the wider extension of recently successful theoretical ideas that emerged from the application of renormalization group methods to statistical mechanics; as a result we have quantitative insight into the profound role of spatial dimensionality and order-parameter symmetry on phase transitions.

For example, in the 1930's Rudolf Peierls and Lev D. Landau suggested theoretically that long-range order cannot exist in a two-dimensional solid or, equivalently, for a one-dimensional density wave in a three-dimensional liquid. A smectic-A liquid crystal is an example of the latter system, and only recently has x-ray scattering from smectics provided experimental confirmation of these ideas. There is also hope that the experimental and theoretical tools that are used to investigate thermotropic phases may be applied to lyotropic liquid crystals and thus provide some insight into the physics of molecules that organize themselves into cell membranes and other biological structures.

Sivaramakrishna Chandrasekhar, the intellectual leader of liquid-crystal research in India, has written an excellent book that covers the basic physical principles used to understand thermotropic phases of liquid crystals and explains their overlap with the rest of physics. There are two chapters on the nematic phase, which has long-range orientational ordering of the molecular axes but no long-range translational ordering; these chapters deal with molecular statistical theories and with phenomenological continuum theories of the nematic state. When chiral molecules order in a nematic state, the optic axis forms a helix with a pitch comparable to the wavelength of light; this phase is usually called "cholestric," and Chandrasekhar has a chapter on its optical and physical properties from a continuum point of view. The many phases of liquid crystals that possess some translational long-range order are called "smectic." There is a phase with a one-dimensional density wave parallel to the molecular alignment directions (smectic-A) and a phase with the density wave at an angle to the molecular axes (smectic-C); these two phases are discussed with a continuum theory. The nematic smectic-A and smectic-A smectic-C phase transitions are also discussed in the context of a Landau (mean-field) model.

Liquid Crystals by Chandrasekhar is nearly isomorphous to Pierre de Gennes's book, *The Physics of Liquid Crystals* (Oxford U. P., 1974); no conscientious reviewer can escape a comparison. To the extent that credit can be given to one person, the application of modern concepts of the condensed states of matter to the complex phases of liquid crystals is associated largely with de Gennes. He is, in my view, the closest living approximation to Landau and it is difficult to match the physical insights that his book on liquid crystals provides. Chandrasekhar, however, has made significant contributions to the statistical theory of nematics and his chapter on this subject is first rate.

I also found the treatment of the optical properties of cholesterics to be an insightful and humane approach to a subject with potential for mathematical complexity. I especially enjoyed the discussion of light scattering from cholestrics and comparison with C. G. Darwin's dynamical theory of x-ray diffraction and the anomalous increase in x-ray transmission near Bragg reflections (the Borrmann effect). The chapter on smectics contains even less than de Gennes's chapter in spite of being written three years later; however, this is an area of relatively little understanding and rapid progress so it is perhaps better saved for a second edition of the book.

Overall, Chandrasekhar's monograph is well written, remarkably free of typographical errors, and especially for the uninitiated, often easier to follow than de Gennes. I recommend that both books should be in institutional collections and the personal libraries of researchers interested in the fundamental physics of this interesting state of matter.

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Thermal Conduction in Solids

R. Berman
193 pp. Oxford U.P., New York, 1976.
$20.50

Soon after World War II, the late Professor Sir Francis Simon initiated research at Oxford on the low-temperature thermal conductivity of insulators, in the hope that this property would yield information about defects in non-metals in the same way that electrical conductivity was being used to study defects in metals. Robert Berman has carried out such measurements at the Clarendon Laboratory for three decades. His studies and those of other groups, as well as the theoretical work to interpret these measurements, have yielded a rich harvest.

Berman, in this rather compact book, has described the microscopic physical processes involved and discussed the essential experimental results and their interpretation. A large part of the book is devoted to heat conduction by phonons in insulators, with special attention given to the role of normal three-phonon processes, and to the important defects that reduce the thermal conductivity. An extensive section on amorphous solids discusses this difficult subject in depth, as well as can be done at present. Electronic thermal conduction in metals is treated, including the role of electron–phonon