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ENCYCLOPEDIA OF CONDENSED MATTER PHYSICS

EDITED BY

FRANCO BASSANI
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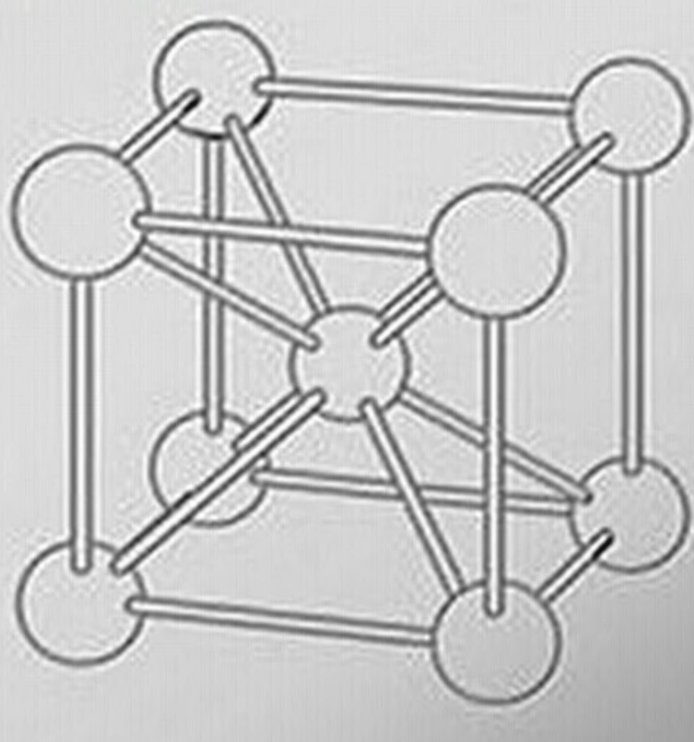
PETER WYDER



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INTRODUCTION

Physics is the paradigm of all scientific knowledge. Over the centuries it has evolved to a complexity that has resulted in a separation into various subfields, always connected with one another and very difficult to single out. Freeman Dyson, in his beautiful book 'Infinite in All Directions', distinguishes two aspects of physics and two types of physicists: the unifiers and the diversifiers. The unifiers look for the most general laws of nature, like the universal attraction between masses and electric charges, the laws of motion, relativity principles, the simplest elementary particles, the unification of all forces, symmetry violation and so on. The diversifiers consider the immense variety of natural phenomena, infinite in their extension, try to explain them on the basis of known general principles, and generate new phenomena and devices that do not exist in nature. Even at the beginning of modern science Galileo Galilei, besides studying the laws of motion and laying down the principle of relativity, was interested in the phenomenon of fluorescence and disproved the theories put forward at his time. He was both a unifier and a diversifier. The full explanation of fluorescence had to await the advent of quantum mechanics, as did the explanation of other basic phenomena like electrical conductivity and spectroscopy.

The past century witnessed an explosive expansion in both aspects of physics. Relativity and quantum mechanics were discovered and the greatest of the unifiers, Albert Einstein, became convinced that all reality could be comprehended with a simple set of equations. On the other hand a wide range of complex phenomena was explained and numerous new phenomena were discovered. One of the great diversifiers, John Bardeen, explained superconductivity and invented the transistor.

In physics today we encounter complex phenomena in the behavior of both natural and artificial complex systems, in matter constituted by many particles such as interacting atoms, in crystals, in classical and quantum fluids as well as in semiconductors and nanostructured materials. Furthermore, the complexity of biological matter and biological phenomena are now major areas of study as well as climate prediction on a global scale. All of this has evolved into what we now call "condensed matter physics". This is a more comprehensive term than "solid state physics" from which, when the electronic properties of crystals began to be understood in the thirties, it originated in some way. Condensed matter physics also includes aspects of atomic physics, particularly when the atoms are manipulated, as in Bose–Einstein condensation. It is now the largest part of physics and it is where the greatest number of physicists work. Furthermore, it is enhanced through its connections with technology and industry. In condensed matter physics new phenomena, new devices, and new principles, such as the quantum Hall effect, are constantly emerging. For this reason we think that condensed matter is now the liveliest subfield of physics, and have decided to address it in the present Encyclopedia. Our focus is to provide some definitive articles for graduate students who need a guide through this impenetrable forest, researchers who want a broader view into subjects related to their own, engineers who are interested in emerging and new technologies together with biologists who require a deeper insight into this fascinating and complex field that augments theirs.

In this Encyclopedia we have selected key topics in the field of condensed matter physics, provided historical background to some of the major areas and directed the reader, through detailed references, to further reading resources. Authors were sought from those who have made major contributions and worked actively in the area of the topic. We are aware that completeness in such an infinite domain is an unattainable dream and have decided to limit our effort to a six-volume work covering only the main aspects of the field, not all of them in comparable depth.

A significant part of the Encyclopedia is devoted to the basic methods of quantum mechanics, as applied to crystals and other condensed matter. Semiconductors in particular are extensively described because of their importance in the modern information highways. Nanostructured materials are included because the ability to produce substances which do not exist in nature offers intriguing opportunities, not least because their properties can be tailored to obtain specific devices like microcavities for light concentration, special lasers, or photonic band gap materials. For the same reasons optical properties are given special attention. We have not, however, neglected foundation aspects of the field (such as mechanical properties) that are basic for all material applications, microscopy which now allows one to see and to manipulate individual atoms, and materials processing which is necessary to produce new devices and components. Attention is also devoted to the ever-expanding role of organic materials, in particular polymers. Specific effort has been made to include biological materials, which after the discovery of DNA and its properties are now being understood in physical terms. Neuroscience is also included, in conjunction with biological phenomena and other areas of the field. Computational physics and mathematical methods are included owing to their expanding role in all of condensed matter physics and their potential in numerous areas of study including applications in the study of proteins and drug design. Many articles deal with the description of specific devices like electron and positron sources, radiation sources, optoelectronic devices, micro and nanoelectronics. Also, articles covering essential techniques such as optical and electron microscopy, a variety of spectroscopes, x-ray and electron scattering and nuclear and electron spin resonance have been included to provide a foundation for the characterization aspect of condensed matter physics.

We are aware of the wealth of topics that have been incompletely treated or left out, but we hope that by concentrating on the foundation and emerging aspects of the infinite extension of condensed matter physics these volumes will be generally useful.

We wish to acknowledge the fruitful collaboration of the members of the scientific editorial board and of the Elsevier editorial staff.

Special thanks are due to Giuseppe Grosso, Giuseppe La Rocca, Keith Bowman, Jurgen Honig, Roberto Colella, Michael McElfresh, Jaap Franse, and Louis Jansen for their generous help.

Franco Bassani, Peter Wyder, and Gerald L Liedl

GUIDE TO USE OF THE ENCYCLOPEDIA

Structure of the Encyclopedia

The material in the encyclopedia is arranged as a series of articles titled by topic and arranged alphabetically. Where several articles deal individually with the specifics of a broader topic, each of these more focused articles is arranged alphabetically after the broader topic. For example, a number of articles are grouped together in the work under the broad topic "Mechanical Properties" by giving the articles a common title prefix.

To help you realize the full potential of the material in the encyclopedia we have provided four features to help you find the topic of your choice.

1. Contents List

Your first point of reference will probably be the contents list. The complete contents list appears in each volume and displays both the volume number and page number of any given article. You will find "dummy entries" where obvious synonyms exist for an article or where we have grouped together related articles under a broader topic. These appear in both the contents list and the body of the text.

Example
If you were attempting to locate material on "creep" via the contents list:

Creep ***See*** Mechanical Properties: Creep

The dummy entry directs you to "Mechanical Properties: Creep."

If you were trying to locate the material by browsing through the text and you looked up "creep" then the following information would be provided in the dummy entry:

Creep *See* Mechanical Properties: Creep.

Alternatively, you may choose to browse through the text of a volume using the alphabetical order of the articles as your guide. To assist you in identifying your location within the encyclopedia a running headline indicates the current article.

2. Subject Classification

In order to ensure that you are able to navigate your way to the correct article we have also provided a list of articles grouped by subject area. Whereas the Contents displays an article according to the alphabetically defined running order, the subject classification groups articles by topic. If, for example, you had failed to find crystal binding in the contents list, you could turn to the Subject Classification as an alternative way of locating articles about this topic:

CRYSTAL BINDING (INTERATOMIC FORCES)

Ionic Bonding and Crystals *M W Finnis*

Metallic Bonding and Crystals *D J Willock*

van der Waals Bonding and Inert Gases *J S Rutherford*

3. Cross-References

All of the articles in the encyclopedia have been extensively cross-referenced. The cross-references, which appear at the end of an article, serve three different functions. For example, at the end of the article "Meso- and Nanostructures" cross-references are used:

i. to indicate if a topic is discussed in greater detail elsewhere

> *See also:* Carbon Materials, Electronic States of; Epitaxy; Excitons: Theory; Nanostructures, Electronic Structure of; Nanostructures, Optical Properties of; Porous Silicon; Quantum Devices of Reduced Dimensionality; Semiconductor and Metallic Clusters, Electronic Properties of; Semiconductor Heterojunctions, Electronic Properties of; Semiconductor Nanostructures; Small Particles and Clusters, Optical Properties of; Transport in Two-Dimensional Semiconductors.

ii. to draw the reader's attention to parallel discussions in other articles

> *See also:* Carbon Materials, Electronic States of; Epitaxy; Excitons: Theory; Nanostructures, Electronic Structure of; Nanostructures, Optical Properties of; Porous Silicon; Quantum Devices of Reduced Dimensionality; Semiconductor and Metallic Clusters, Electronic Properties of; Semiconductor Heterojunctions, Electronic Properties of; Semiconductor Nanostructures; Small Particles and Clusters, Optical Properties of; Transport in Two-Dimensional Semiconductors.

iii. to indicate material that broadens the discussion

> *See also:* Carbon Materials, Electronic States of; Epitaxy; Excitons: Theory; Nanostructures, Electronic Structure of; Nanostructures, Optical Properties of; Porous Silicon; Quantum Devices of Reduced Dimensionality; Semiconductor and Metallic Clusters, Electronic Properties of; Semiconductor Heterojunctions, Electronic Properties of; Semiconductor Nanostructures; Small Particles and Clusters, Optical Properties of; Transport in Two-Dimensional Semiconductors.

4. Index

The index will provide you with the volume number and page number of where the material is to be located, and the index entries differentiate between material that is a whole article, is part of an article or is data presented in a table or figure. Detailed notes are provided on the opening page of the index.

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