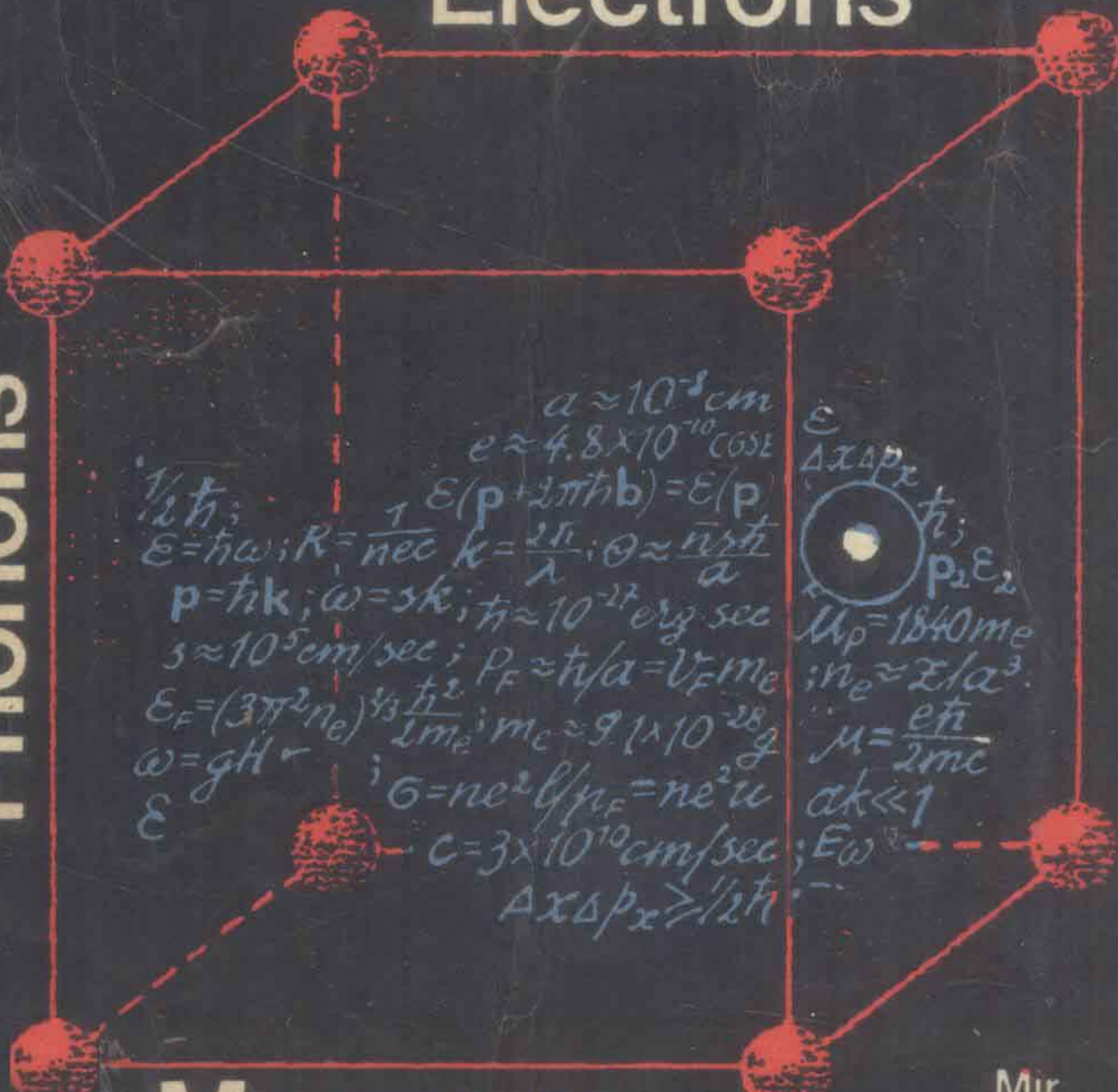
M. I. Kaganov

Electrons Phonons Magnons



Mir Publishers Moscow

Further suggested popular science books on physics from Mir Publishers to be issued in 1981

LASER AGE IN OPTICS

L. TARASOV, Cand. Sc.

This is a popular science book concerned with new trends in optics arising from the development of the laser. The author successfully combines a popular style of presentation with, when necessary, a serious scientific treatment of the problems involved. Consequently, the book can be recommended not only for high school students but also for a layman adult reader wanting to study in some detail the principles involved in lasers, optical holography and nonlinear optics. The reader will find a popular, vivid and intelligent presentation of many elusive concepts which, as a rule, are either not covered at all in literature of this kind or only in passing.
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Contents. From Incoherent to Coherent Optics. Optical Holography. Nonlinear Optics.

PHYSICS FOR EVERYONE (in 4 books)
Book 3. Electrons

A. KITAIGORODSKY, D. Sc.

The fourth Russian edition of *Physics for Everyone* by Lev Landau and Alexander Kitaigorodsky was published in 1978 as two separate books: *Physical Bodies* (Book 1) and *Molecules* (Book 2). They were published in English in 1980 period. This is the first publication of Book 3 of this series. It was written as a sequel to *Physics for Everyone*. This book deals with physical phenomena in which our attention is focused on the next level in the structure of metal—the electrical structure of atoms and molecules. Electrical and radio engineering, without which the existence of today's civilization is inconceivable, are based on laws governing the motion and interaction of electrical particles, primarily electrons, the quanta of electricity.
The main subjects of this book are electric currents, magnetism and electromagnetic fields.
Contents. Electricity. Electrical Structure of Matter. Electromagnetism. Summary of Electrical Engineering. Electromagnetic Fields. Radio.

Book 4. PHOTONS AND NUCLEI

A. KITAIGORODSKY, D. Sc.

The book concludes the series *Physics for Everyone* by the world-renowned scientist, winner of the Nobel and Lenin prizes, academician Lev Landau and the distinguished physicist Alexander Kitaigorodsky.
This book discusses in a simple and easy-to-understand manner the phenomena of electromagnetic waves, thermal radiation, and current treatment of spectroscopic analysis. Provides an introduction to the field of nuclear physics and explains the most common types of lasers. Outlines principal aspects of special theory of relativity and quantum mechanics.
Contents. Soft Electromagnetic Radiation. Optical Instruments. Penetrating Electromagnetic Radiation. The Unification of Mechanics. Structure of Atomic Nuclei. Energy Surrounding Us. Physics of the Universe.

М. И. Каганов

Электроны. Фононы. Магноны

Издательство «Наука»
Москва

ИЗДАТЕЛЬСТВО МИР

M. I. Kaganov

Electrons Phonons Magnons

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На английском языке

Contents

So long, the stone!
Long live, the wave!
D. Samoilov

Instead of an Introduction

Languages of Science

When science perceives the surrounding world and transforms "things in themselves into things for us", when it masters new fields and turns its achievements into everyday tools of humanity, it also fulfills one additional function. Namely, it *composes a picture of the world* which is modified by each subsequent generation and serves as one of the most important characteristics of civilization. The picture of the world, that is, the sum total of humanity's information about nature, is stored in hundreds of volumes of special monographs and in tens of thousands of articles in scientific journals.

Strictly speaking, this picture is known to humanity as a whole but not to any single person. One man, even with the best possible education, knows the details of only a small fragment of the total picture and is satisfied with approximate information about everything that lies beyond his special field.

The difficulties in obtaining the picture of the surrounding world result not only from the unlimited diversity of data but also from the existence of specialized languages. These languages are means of communicating and developing logical structures within separate scientific domains; these languages are totally devoid of meaning for a scientist working in a remote field, and are only approximately comprehensible to those working in an adjacent field. Generalization of scientific results and the composition of the picture of the world demand that the descriptions be translated from a specialized language into an ordinary (universal) language. And it is here that the obstacle is encountered: specialized languages are formalized to a much higher extent than any ordinary everyday language.

The translation is always difficult. This is especially true for a translation from a scientific language into a language in which the meaning of each concept is not strictly defined, but can be easily modified under the influence of the experience accumulated by the user of the language. Pictures of the world created in the minds of different people are different not only because the people have digested unequal amounts of information but also because this information is encoded into different languages. A biologist constructs a world picture quite different from that of a physicist. An engineer's picture is much more "mechanistic" than that of a specialist in the humanities.

Popular science literature is an attempt to translate from a rigorous scientific language into a less formal language.

It would be wrong to think that scientists, speaking or thinking about their professional topics, always employ only rigorously formalized scientific terminology. Far from it. It is not difficult to find, by listening to arguments in a scientific discussion, by paying attention to the wording of reports delivered at conferences and seminars, and by simply listening to specialists talk informally during these conferences, that each branch of science generates two languages. One rigorous and precise, the other much less rigorous.

This second language is a mixture of special terms and everyday words. Repeated use of the latter gives to these words a very peculiar meaning that is unlikely to be found even in the best encyclopaedic dictionary. What is essential, however, is that the addition of the scientific meaning does not suppress the emotive flavour of the word.

There can be no doubt that the words of any human language possess a magic power of stirring up chains of associative images, prodding the mind, and stimulating the emotions. This makes the word a very powerful tool. This explains why a scientist searching for a strict solution uses lively colloquialisms when arguing with the opponents of his point of view; he does not restrict his language to a scientific lingo whose words are precise but lack emotion.

Popular science literature familiarizes the reader with the "colloquial" language of science.

Conventional words often entail allusions which are marginal in a scientific context and therefore interfere with the understanding of a statement. The translation from the scientific language to a conventional language gives rise to losses. Precision is sacrificed, which is an unavoidable price of simplification. It is possible, however, to try and reduce the *load of unnecessary allusions* that trail after each everyday word.

Take the verb "to decay". A nonphysicist learns from the unabridged edition of the *Random House Dictionary of the English Language* (1966) that "to decay" means:

> vi. 1. to decline in excellence, prosperity, health, etc.; deteriorate. 2. to become decomposed; rot. 3. (*phys.*) (of a radioactive nucleus) to change spontaneously into one or more different nuclei in a process in which particles, as alpha particles, are emitted from the nucleus, electrons are captured or lost, or fission takes place.

A physicist will try to explain, however, that the *decay* of a neutron into a proton, electron, and antineutrino does not mean that prior to the decay the neutron was composed (in separate parts) of the proton, electron, and antineutrino. The word "decay" means here, the physicist says, the "transformation", despite everybody referring to it as "decay".

Another example: "collision". The same dictionary states:

> n. 1. the act of colliding; a coming violently into contact; crash (as railway trains or ships). 2. a clash; conflict. 3. (*phys.*) the meeting of particles or bodies in which each exerts a force upon the other, causing the exchange of energy or momentum.

But in solid state physics an electron-phonon *collision* means that the electron has "absorbed" the phonon.

A comical analogy: a wolf-hare collision. After the collision, the wolf is alone in the field.

Science gives rise to new concepts almost everyday, so that new terms have to be created constantly. Words from ordinary everyday language are often borrowed to produce these terms. It is popular nowadays to borrow words from a domain far removed from science. The physics of elementary particles, for example, has incorporated "strangeness", "charm", "colour", and "flavour".

This vogue may be connected not so much with the unrestrained inventiveness of the creators of new physics as with their attempts to avoid the concomitant introduction of unwanted concepts. The author of the name "quark" for a subnucleon particle (M. Gell-Mann) was very conscious (or felt intuitively) that the allusions surrounding Joyce's quarks cannot affect the notion of the properties of the (then) hypothetical subparticle.

Popular science literature helps the layman to perceive the scientific content of words that were extracted from everyday language and transferred to unfamiliar surroundings.

But the main target of popular science literature is, of course, to acquaint a great number of readers with the progress of science.

The book you are reading now is a popular science book on the quantum physics of the solid state. We are aware of the numerous popular science books devoted to solid state physics. The present book is different in that it is an attempt to concentrate *exclusively* on the quantum physics of the solid state and to disregard applications. It is a book about the methods of interpreting macroscopic effects, about the relationship between solid state physics and quantum mechanics, about the creation and use of new concepts... . I have also pursued another goal—to "lift the veil" by explaining *how* the results are obtained and not restricting the presentation to an itemization of the results. The reader will be the judge of whether the attempt has failed or succeeded.

Writing this book was a pleasure, and I "tortured" my friends and relations, and above all my wife, by having them listen to my reading some of the passages aloud. They were always patient listeners, and deserve my deepest gratitude.

Chapter 1

On Physics in General and Quantum Mechanics in Particular

To understand means to simplify

Man comprehends the world in the process of his never-ending adaptation of his surroundings to his needs. The results of this activity are both the things the man produces and a set of ideas about the surrounding world. On the one hand, this set of notions becomes continuously more and more detailed (this is a result of our studying the world), and, on the other hand, the concept of this world becomes more and more generalized. Let us discuss the latter aspect of the process of cognition.

People usually think that with each new theory and the ensuing formulation of new concepts, the picture of the world grows more complicated. It is often said that the physics of today is fantastically complicated while it was much simpler in the past. This attitude was even expressed in a quatrain consisting of an eighteenth century epigram:

> Nature, and nature's laws, lay hid in night:
> God said, *Let Newton be*! and all was light.
> (*Alexander Pope*)