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Dynamical and informational aspects of physical systems

Dynamics and information. Kadomtsev B.B.
(Moscow: Uspekhi Fizicheskikh Nauk, 1997) 400 pp.

The book under review is concerned with the dynamical and informational aspects of physical systems. All its sections may be followed by students of senior courses of universities with a physics profile. Meanwhile the book contains a lot of novel factual data which were known previously only from special journal papers. It should be extremely useful for professors giving courses of general and theoretical physics in high schools. Being a lecturer of theoretical physics in the Moscow Institute of Physics and Technology, I found various new facets in the description of, one might think, traditional subjects of theoretical physics. Let us enlarge on four such problems.

(1) **Fluctuations of particle number in an ideal gas** (Section 23). Usually we discuss this problem with students in the course of statistical physics by deriving the expression for fluctuations from the binomial distribution, or from the Gibbs distribution, or from the principle of minimal work. The simple derivation from first principles in the book under review is much more direct and clear.

(2) **The equilibrium Maxwellian distribution for the velocities of gaseous species** (Section 19). In most textbooks on statistical physics [see, for example, L D Landau, E M Lifshitz, *Statistical Physics*, Part 1 (Moscow: Nauka, 1993)] the Maxwellian distribution is derived from the general Gibbs distribution. But here the Maxwellian distribution is obtained in a preferable manner from the physical point of view. The author starts with Newton's second law for a molecule propelled by a random force due to chaotic collisions with other molecules and by the force of friction. The latter imitates relaxation of the velocity of a given molecule due to random distortion of its trajectory by collisions with other molecules. The author explains in detail the difficult question about the difference between these two forces. Then he derives the Fokker – Planck equation with physically determined coefficients by means of molecular averaging over random collisions. The stationary Maxwellian distribution of molecules in velocities follows from the Fokker – Planck equation for large times. Beyond that point such a derivation is important in giving the time for relaxation to the Maxwellian distribution.

(3) **The second quantization technique** (Section 47). This technique is considered starting from more illuminating premises than in other textbooks. I think that the second quantization technique could be taught in a course of quantum mechanics using only 5 pages of text from this book.

(4) **Natural convection** (Section 49). The equations of the Lorentz model for convection in a liquid are derived and the linear approximation is considered analytically along with nonlinear effects. In the framework of this model the phenomena of the strange attractor and self-organization are explained quite well. It is my opinion this material should be included in a lecture course on hydrodynamics.

Besides this, the book considers a lot of modern problems in quantum theory absent from existing textbooks, but which might be given to students of the course of quantum mechanics. Many of these problems were first discussed in scientific journals during 1990 – 1996. Let us enumerate these problems:

(1) the parabolic Leontovich equation for the time evolution of the envelope of a quantum-mechanical wave packet (Section 9);

(2) the interpretation of Feynman path integrals for the quantum-mechanical transition amplitude as the amplitude of *intention* of a quantum particle transition from one point in space to another for some time interval (Section 12);

(3) the paradox of wave function superposition for Schrödinger's cat being both alive and dead (Section 16) with an important accent on the requirement of introducing wave function collapse into the scenario of their evolutions;

(4) a simple, but detailed description of so-called *entangled* quantum states (Section 25);

(5) Bell inequalities for a classical theory of hidden parameters (Section 26) which tried to substitute the quantum-mechanical uncertainty relations;

(6) the so-called *teleportation* of a quantum state from one point to another (Sections 27, 28, 44) (as well as 'quantum telegraph') which is presently being actively discussed at seminars on theoretical physics. The underlying phenomenon consists in the collapse of the wave function relating to a system of two quantum objects interacting with a classical system, i.e. during measurements. As a result one of the possible coherent states for the system of two objects is selected, i.e. state determination for one of the objects automatically selects the state of the other. The main result of the theory is the possibility of quantum information communication unrestricted by the speed of light! It is possible over distances less than cT, where c is the speed of light, and T is the time for irreversible relaxation of the quantum system being considered. It was found that no contradiction with Einstein's theory of relativity arises. This problem has been considered in detail, since the author of the book under review is also a co-worker on the theoretical interpretation of this effect;

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(7) the microscopic Klimontovich equations for the description of classical molecular chaos (Section 33) taking into account the modification of the Boltzmann kinetic equation due to fluctuations of the collision integral. This additional term presents the external random force which permanently resumes thermal fluctuations (we discussed this force above with respect to the derivation of the Maxwell velocity distribution). What is more, the author gives here simple and clear explanation of the concept of Kolmogorov – Sinai entropy;

(8) the quantum paradox of Zenon (Section 36). It was found that decay of any unstable quantum system can be forbidden by means of *frequent* measurements of its probability of staying in the initial state;

(9) the Brownian motion of a quantum particle (Section 37). Unlike in journal papers, where the mathematical techniques are usually based on the Heisenberg representation, the author takes a more physical approach. The latter starts from the definition of the initial state of the Brownian particle described by a spatially extended wave function;

10) the difference between the wave functions of gaseous atoms and plane waves (Section 39);

(11) quantum chaos in a gas (Section 40). The difficult problem of a small displacement of a quantum-mechanical wave packet for a gas atom at each real scattering is explained in simple and clear manner;

(12) the Sokolov effect (Sections 41 – 46). The problem lies in the fact that when an excited hydrogen atom is flying in proximity to a metal diaphragm, it is irreversibly polarized, i.e. the atom acquires a dipole moment. This means that interference coupling between excited hydrogen states and metal polarized states is of principal importance for transitions between the excited states of atomic hydrogen in the process of wave function collapse;

(13) an example of self-organization in a plasma ball (Section 50). The most interesting thing here is the introduction of the notion of *negative entropy* (or *negentropy* for short). This is the degree of regularization in the self-organization of a many-body system.

The commentaries by the author to some chapters at the end of this book are very useful. They are for more curious readers who are not satisfied by the explanations in the main text.

Furthermore, in a number of cases the author underlines that at present different scientists give various answers to many problems of modern quantum theory (for example, the problem of wave function collapse on measurements, p. 381). The author always gives his own point of view on these issues, but he never insists upon his solution as 'final truth'.

No doubt, we should welcome the publication of this book. Both teachers and students may find here many new and interesting things on the dynamics of physical systems. It would not be out of place also to emphasize the optimal combination of qualitative approaches and calculations in the solution of equations.

V P Kraĭnov