

Works of I. M. Lifshitz on Disordered Systems

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The theory of disordered systems occupied a special place in the scientific activities of I. M. Lifshitz. Indeed, this new and rapidly developing branch of solid state physics—one of “hot potatoes” of modern physics—emerged as an independent discipline essentially due to his ideas and works. Here, I. M. Lifshitz passed all the stages in the development of a new field: the elaboration of many basic concepts, a clear-cut formulation of fundamental principles, the construction of adequate investigation methods, and, finally, an analysis of important particular results. I. M. Lifshitz was engaged in studying disordered systems from 1937, when his first paper on the subject appeared,² till his last days: the last Lifshitz paper on disordered systems is published in this issue of the Journal. The present paper is a brief survey of important results obtained by I. M. Lifshitz in the theory of disordered systems.

1. SCATTERING AND ABSORPTION OF WAVES IN SOLID SOLUTIONS AND A CORRELATION OF ATOMIC POSITIONS IN THEM: 1937–1950

The appearance of the first work of the series [III.2] was initiated by Landau's paper “X-ray scattering in crystals of a variable structure” (1937) which considered a layered crystal formed by layers of random, uncorrelated thicknesses. In paper [III.2], which appeared right after the Landau paper had been published, the same problem was solved for a disorder of a more general form, and even in this paper the author raised the question of the origin of the disorder: the aim of the paper was “to find a distribution in a

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² The paper was published in *Phys. Z. Sov.* 12:623–643 (1937). in English: Russian translation [III.2] (this numbering system for papers by Lifshitz refers to the “List of Selected Works by I. M. Lifshitz,” which appears in this issue immediately preceding the present paper.

crystal of variable structure proceeding from a certain mechanism of structure formation.” The statistical properties of disorder were also considered in great detail in [III.5], though these papers deal mainly with (in modern terms) calculating the correlation functions of solid solutions (the Ising model). In 1938, I. M. Lifshitz introduced the presently acknowledged classification of disorder types in disordered systems [III.4]: “...we shall consider two types of deviation from a perfect lattice: the first type is a disordered distribution of atoms with different scattering abilities at lattice sites [site disorder]; the second type of deviation is related to the distortion of the spatial lattice site distribution [structural disorder].

The series of works [III.8] is very impressive.

First, in these papers I. M. Lifshitz showed, for the first time, the existence of new “resonance” (“local” in modern terminology) frequencies separated from the continuous spectrum, and analyzed in detail the contribution of the corresponding modes to crystal characteristics. Here we mean the states of quasiparticles, arising near local defects, which play a very important role in various fields of modern physics.

Second, the papers consider, both explicitly and implicitly, many fundamental ideas of the theory of disordered systems, which have now been commonly accepted.

For example, a problem was raised, for the first time, concerning the disorder-induced reconstruction of the quasiparticle spectrum: “...the existence of impurities gives rise to new resonance frequencies, as well as to the shift and broadening of the “old” frequencies.... The study of vibrations in an imperfect lattice is, in principle, interesting if only because in this case the method of plane waves is inapplicable.”

For the first time, the selfaveragedness of an additive physical quantity was explicitly proved for the dipole moment of an isotopically disordered crystal:

$$\mathbf{P} = \mathbf{P}_0 \left(1 + \frac{\alpha z}{z - z_0} \sum_{k=0}^{\infty} S_k (\alpha z)^k \right) \quad (1)$$

$$\alpha = \Delta m/m, \quad z = \omega^2$$

The proof is based on the fact that when the number of sites N in the sample tends to infinity ($N \rightarrow \infty$), all the coefficients S_k of the perturbation series (1) become nonrandom:

$$\lim_{N \rightarrow \infty} (\overline{S_n S_m} - \overline{S_n} \overline{S_m}) = 0$$

In 1957, this proof was, in fact, rediscovered by Kohn and Luttinger in their paper devoted to calculating the kinetic characteristics of metals with impurities.

I. M. Lifshitz pointed out, for the first time, that disorder-induced small perturbations "...may be of two essentially different types:

(1) a large fraction of sites is occupied by 'foreign' atoms, but these 'foreign' atoms differ little from the 'host' ones...

(2) a relatively small number of sites is occupied by 'foreign' atoms, but these atoms differ significantly from the 'host' atoms...." In accordance with this classification, expansions of spectral characteristics were constructed with respect to the parameter $\Delta m/m$ for isotopic disorder (1) and with respect to the concentration c of "foreign" atoms for case (2).

The fine structure of the vibration impurity band was also considered for the first time. "...The appearance of new resonance frequencies in this approximation corresponds to only one impurity atom in the lattice... Retaining the higher-order terms in the concentration expansion, we would obtain a greater number of new resonance frequencies that remain isolated. The forces of these new frequencies would be proportional to the next concentration powers."

The direction discussed in this section was further developed in a number of works, among which papers [III.11] and [III.20] are of most importance.

2. LOCAL PERTURBATION THEORY: 1945–1952

The papers discussed in the present section deal with dynamical problems, which naturally arise from the works of the previous series. I. M. Lifshitz came to the concept of a local (degenerate) perturbation precisely in connection with the study of local frequencies in the phonon spectrum. It should, however, be noted that the applicability of the general local perturbation theory developed in [IV. 1, 2; II. 1] goes far beyond the framework of the phonon problems.

A perturbation V is called degenerate if the corresponding operator sends any state vector into a linear combination of given state vectors whose number is much smaller than the total number of the states of the system. A typical example of such a perturbation is the one which is sufficiently well localized in all or in certain directions (local defect, vacancy; linear defect, dislocation; planar defect, crystal surface).

In these papers, I. M. Lifshitz rigorously formulated in rather general terms and, in fact, completely solved the problem of analyzing spectrum modification under degenerate perturbations; he obtained efficient relations for modified spectral characteristics of a macroscopic crystal. For the first

time, I. M. Lifshitz derived and analyzed the equation for the local level E_0 in a general case:

$$1 + \int \frac{C(E) dE}{E - E_0} = 0$$

$$C(E) = \varepsilon E \int_{\omega^2(k)=E} \frac{d\sigma_{\mathbf{k}}}{|\nabla \omega^2(\mathbf{k})|}$$

where ε is the parameter describing the intensity of a local perturbation V , $\omega^2(k)$ is the dispersion law for a perfect crystal. He introduced the spectral shift function

$$\xi(E) = N_0(E) - N(E)$$

which is equal to the difference of the integrated densities of states for the unperturbed and perturbed Hamiltonians, obtained explicit expressions for this function

$$\xi(E) = \pi^{-1} \operatorname{Im} Sp \ln [1 - G_0(E - i0)V]$$

$$\xi(E) = \pi^{-1} \arctan \frac{\pi C(E)}{1 + f(C(E') dE')/(E' - E)}, \quad \dim V = 1$$

and demonstrated its important role in the calculation of physical quantities of a locally perturbed system. A relationship was established between the spectral shift function and the phase of the wave scattered from a local perturbation [IV.2, II.1].³ For the first time, I. M. Lifshitz derived the trace formula

$$Sp\{\varphi(H) - \varphi(H_0)\} = \int \xi(E) \varphi'(E) dE + \sum_g (\varphi(E_g) - \varphi(E_g^{(0)}))$$

Being an important tool for constructing the concentration expansion (the construction was completed some time later), the formulas presented above and the corresponding mathematical apparatus became the origin of a new direction in mathematical and mathematical-physical investigations (M. G. Krein, L. D. Faddeev, V. S. Buslaev, and M. S. Birman), and have now been widely used in the theory of completely integrable nonlinear evolution equations.

The methods of local perturbation theory were used in [III.15] to study wave scattering from a small inhomogeneity in a crystal lattice. The study was performed in terms of an arbitrary phonon dispersion law and for an

³ See also *Uchenye Zapiski* of Kharkov State University, 27:105–107 (1948) (in Russian).

iso-frequency surface $\omega^2(k) = E$, which shows that even at that time I. M. Lifshitz clearly understood an important role of the dispersion law in an analysis of dynamic and static properties of quasiparticles. The effectiveness of such an approach was fully demonstrated in brilliant Lifshitz's works on the electron theory of metals.

At present, the apparatus of the theory of local modes has become an integral part of the solid state theory formalism; many important physical effects have been calculated with the aid of this apparatus (in particular, the existence of quasilocal modes has been predicted and their role in the kinetics of imperfect crystals analyzed).

3. CONCENTRATION EXPANSION: 1955–1957

The works of this series were initiated by experiments on solid solutions of hydrogen isotopes. The main concepts of the theory of disordered systems, such as quenched disorder of an arbitrary statistical nature, the self-averagedness of additive quantities of the theory, the possibility of expanding the quantities in the powers of concentration, and calculation of the expansion coefficients, act in these works as thoroughly elaborated modern notions and are effectively used for solving a very interesting problem of that time—the structure and properties of solid solutions of solified gases [IV.7].

In 1955, in paper [IV.4] I. M. Lifshitz used, for the first time, the term *a disordered system* in the sense we understand it now, and rigorously formulated the property of selfaveragedness of the density of states: “For a sufficiently large crystal, the true value of the spectral density coincides with its mathematical expectation.” In the same paper, the concentration expansions for the spectral shift function, for the density of states, and for the free energy of a solid solution were obtained in a general form using the trace formula and methods of local perturbation theory:

$$F - F_0 = N \int dE \varphi'(E) \left\{ C \xi_1(E) + \frac{C^2}{2} \sum_{\mathbf{r}} W_{\mathbf{r}} [\xi_2(E, \mathbf{r}) - 2\xi_1(E)] + \dots \right\}$$

where $W_{\mathbf{r}}$ is the pair correlation function of impurities. It was shown that the concentration expansion is of more general form than the perturbation expansion, and the boundary shift of the initial spectrum was determined for the first time:

$$\rho(E) = \rho_0 \left(E - \frac{\xi_1(E)}{\rho_0(E)} \right) \left[1 + C \left(\frac{\xi_1}{\rho_0} \right)' \right]^{-1}$$

This formula was derived by calculating explicit first-order corrections in the concentration and writing the final result with an overestimated accuracy. Later, in the sixties, this formula was obtained in a more consistent fashion by many authors, including I. M. Lifshitz, with the aid of the self-consistent Hartree–Fock-type methods, summation of ladder diagrams, etc. An analysis of paper [IV.4] shows that I. M. Lifshitz completely understood the qualitative picture of a complicated structure of the discrete spectrum in the impurity band for low-impurity concentrations: “As it follows from Eq. (23), as well as from the physical meaning of the quantities, the point $E^{(1)}$ [a one-center local level] is a limit point for the sequence of points $E^{(2)}$ appearing in the terms $\sim c^2$; similarly, each point of the sequence $E^{(2)}$ is a limit point for the sequence $E^{(3)}$ of the spectrum points that are obtained via the substitution of three atoms and appear in the terms $\sim c^3$; etc.” Later, this fine structure was obtained both in a theoretical analysis of the one-dimensional models and in numerical calculation of the density of states.

The investigations performed till 1956 were summed up in the review [II.3]. It was pointed out that an analysis of a disordered system that lacks translational invariance requires a nonconventional mathematical apparatus: “... It is known that the existence of translational symmetry greatly simplifies the mathematical aspect of the problem... Other results, at least qualitative, are not related to this fact, but they cannot be proved within the framework of the present theory whose methods are entirely based on the existence of a periodic crystal structure.”

In the sixties, the concentration expansion method became a basis for various self-consistent methods, both “one-particle,” i.e., based on a first-order approximation in the concentration, and “many-particle.” At present, the concentration expansion method, as well as its modified and self-consistent versions, have been developed further and are now being used as an efficient instrument for studying a wide range of phenomena and properties in different disordered systems (electronic, vibrational, and magnetic).

4. THE IMPURITY BAND: 1963

From 1957 to 1963, no Lifshitz works on the theory of disordered systems were published. In all probability, this was mainly due to his intensive work at that time on the electron theory of metals, which culminated in the creation of a well-known “fermiology.” Nevertheless, I. M. Lifshitz did not cease mediating on some problems in the theory of disordered systems, and a number of fundamental works were written in the sixties, which played an extremely important role in the development of the theory.

Apparently, the original Lifshitz idea was “to extend the results obtained for phonons and the corresponding methods to electrons in a crystal” [II.3]. However, while working at paper [IV.8], he proceeded much further. As a result, a new “basis” model appeared in the theory, a probabilistic approach was used for the first time to interpret the density of states, and it was clearly demonstrated that for low-impurity concentrations all states in the impurity band are localized.

Proceeding from the definition of the density of states and from its self-averagedness, one may interpret $\rho(E) dE$ as the probability (generally nonnormalized) that an arbitrary level is contained within the interval $(E, E + dE)$. Using this consideration, I. M. Lifshitz developed a very efficient method of calculating the density of states. He noticed that there exist a number of remarkable cases where in the parameter region of interest the density of states is formed due to a rather narrow, optimal class of realizations. This means that in the basic approximation, in which the remaining part of the distribution is neglected, one may concentrate only on a few constructively defined representative configurations. An obvious advantage of the method is that it predicts the character of an overwhelming fraction of the states that form $\rho(E)$ in a given range of energies and parameters. The effectiveness of this general conception was demonstrated in the study of the impurity band spectrum in a certain spectral disorder model, which is now called Lifshitz’s model.

Point scatterers (of δ -function type in the one-dimensional case) are the simplest realization of local perturbations in the electron system. By arranging these scatterers in space at random, one obtains a very profound model of structural disorder, and precisely in terms of this model the impurity band of the electron spectrum was studied in paper [IV.8]. An allowance for low-impurity concentration lies mainly in changing the energy scale. In this approximation, the energy levels and states admit a transparent geometric systematics. In the new energy variable, the density of states become universal and independent of the concentration. In the far neighborhood of a local level, i.e., at the impurity band tails, the density of states is formed by pairs of closely spaced impurities, while near a local level it is formed by individual impurities which are rarefaction centers of a growing volume, so that the density of states has a gap at the center of band. Although in the basic approximation the energy levels may depend on the positions of a large number of centers, the wave functions are always localized at one or two centers: “As can be seen from the analysis just performed, the states that are collective for all impurity centers, i.e. those that are ‘spread’ over the entire crystal volume, as is the case with a periodic structure, have zero probability.”

Lifshitz’s model of structural disorder is extremely profound and

realistic. At the same time, it is rather complicated, and this is, probably, the reason why until recently this model was studied in a rather small number of papers as compared with those dealing with another, popular one-body “basic” model—Anderson’s model—which is based on substitutional disorder. It is believed, however, that as the theory of disordered systems is developed further, Lifshitz’s model will play an ever-increasing role.

Apparently, I. M. Lifshitz was fully conscious of that. Permanently and with unremitting interest did he return to the model. The last Lifshitz paper⁴ published in this issue also deals with the structural disorder model. In this work it is shown, in particular, that just near a local level one has to take into account corrections to the basic approximations due to a new class of optimal configurations, so that the gap in the density of states becomes less pronounced.

5. REVIEW: 1964

The next fundamental work of that period was the well-known review [II.8] in which I. M. Lifshitz formulated a program for analyzing the spectrum of elementary excitations in disordered systems. The main attention was paid to studying the spectrum in the vicinity of singular points, since “precisely in this region the quantum states and their systematics are completely rearranged. Near these points, the perturbation is no longer small in the sense of small effect on the states or on the spectrum.” As the singular points (possibly, in the asymptotic sense), we may note, above all, spectral boundaries, one-center local levels, boundaries of the initial spectrum, etc.

As a realization of the program, the review presents many new results, so that we call it a review only conditionally. Among these results, one should note, first of all, the concept of genuine spectral boundaries and the construction of a physically clear and profound spectral pattern near the boundaries E_g , which were called later fluctuation boundaries [I.3]. The neighborhood of a fluctuation boundary is apparently a much more fundamental example (as compared to the impurity band) of the spectral region where the approach based on optimal configurations is extremely effective. I. M. Lifshitz showed that, to within the logarithmic accuracy, the density of states in this region is of the form

$$-\rho(E) \sim \left| \frac{E - E_g}{E_g} \right|^{-d/2}, \quad E \rightarrow E_g \quad (2)$$

(Lifshitz’s singularity) and is determined by fluctuations with a maximal concentration of impurities at which the corresponding quantum states are

⁴ *Journal of Statistical Physics*, this issue, p. 37.

localized. The review contains, in fact, the fundamental ideas of the method which, at the end of the sixties, became known as the optimal fluctuation method. While advancing this "optimal" ideology, I. M. Lifshitz obtained, for the first time, the asymptotic behavior of the density of states on the left of the potential mean value \bar{U} in the three-dimensional model of weak point scatterers of high concentration

$$-\ln \rho(E) \sim \left| \frac{\bar{U} - E}{\bar{U}} \right|^{1/2}, \quad \bar{U} - E \ll \bar{U}$$

A simple analysis of the arguments presented in the review shows that in the d -dimensional case this formula turns into

$$-\ln \rho(E) \sim \left| \frac{\bar{U} - E}{\bar{U}} \right|^{2-d/2} \quad (3)$$

In 1966, it was rederived by B. Halperin and M. Lax, and by J. Zittarz and J. Langer, and became rather popular.

The review also presents many other important results. In particular, the study of the conditions for the occurrence of a local level generated by one or several impurities, calculation of the shift of the initial part of the spectrum by summing an infinite series of most singular terms in the concentration expansion of the density of states, etc. I. M. Lifshitz pointed out in the review a specific role of the lower boundary of the phonon spectrum acoustic branch: this boundary is not shifted by any disorder, and state systematics in the nearest neighborhood of the boundary does not change (later, such boundaries were called stable [I.3]).

We may say in conclusion that this review, together with the familiar review by N. Mott and U. Twose, marked the beginning of a modern stage in the development of the theory of disordered systems, which led to a great surge of interest in the field and to a large number of papers which undoubtedly carried the imprint of Lifshitz's ideas and methods.

6. FLUCTUATION LEVELS: 1967–1976

Advancing the concept of fluctuation levels, I. M. Lifshitz constructed in 1967 a consistent quantitative theory of these levels [IV.9], which completely rested upon the "optimal" ideology. Interestingly, Lifshitz's theory according to both its spirit (the existence of a unique, to within a shift, optimal fluctuation) and the mathematical apparatus used (the steepest descent method), resembles Landau's theory of second-order phase transitions. An essentially new point, completing the "optimal" ideology, was the

macroscopic description of an optimal fluctuation in terms of the coordinate-dependent impurity concentration $c(\mathbf{r})$, which became possible in the limiting case of the so-called low-intensity impurities. All this led to the self-consistent equations

$$\begin{aligned} \sigma'(c) - \sigma'(c_0) &= \beta \int u(\mathbf{r} - \mathbf{r}') \psi_0^2(\mathbf{r}') d\mathbf{r}' \\ - \Delta \psi_0(\mathbf{r}) + \psi_0(\mathbf{r}) \int u(\mathbf{r} - \mathbf{r}') \psi_0^2(\mathbf{r}') d\mathbf{r}' &= E \psi_0(\mathbf{r}) \end{aligned}$$

[where $\sigma(c)$ is the entropy of the impurity “gas”] from which the form of the optimal fluctuation of $c(\mathbf{r})$, the wave function $\psi_0(\mathbf{r})$, and the density of states at different energies could be found. In the vicinity of the mean potential value, long-wavelength Gaussian fluctuations of the concentration are optimal and lead to the “white-noise” asymptotic behavior (3). Near the boundary, they turn to local fluctuations of the maximal concentration, and the density of states is described by Eq. (2). At a low-impurity concentration, the transition from one regime to the other occurs in a very narrow energy interval.

The idea of macroscopization enabled the applicability limits of the optimal fluctuation method to be widened considerably and, which is even more important, the method to be made more universal as compared with the approach developed in 1966 by B. Halperin and M. Lax and by J. Zittarz and J. Langer. Precisely this feature of Lifshitz’s approach proved to be decisive in the extension of the optimal fluctuation method to other classes of scatterers (screened Coulombic impurities) and to other classes of objects (biopolymers), as well as in its various applications (viz., in the theory of heavily doped semiconductors) carried out by B. Shklovsky and A. Efros.

Later, the “fluctuation ideology” led I. M. Lifshitz to the concept of fluctuons—electron states self-localized at such fluctuations—and to the development of their thermodynamics [IV.10] (the theory of fluctuons was constructed independently, and at the same time, by M. A. Krivoglaz).

Soon it was understood that the genuine large parameter in the theory of fluctuation levels is the excess number of impurities at an optimal fluctuation. Near the boundary, however, this parameter tends to infinity for any impurity concentration, and if the concentration is low the fluctuation region broadens and almost reaches the mean potential value. This idea became a starting point for the approach ([II.11]; see also [I.3]) to calculating the density of states in the fluctuation region based on a special variational principle. The applicability of the principle was no more restricted by the condition of macroscopic description, and, therefore, the above approach enabled I. M. Lifshitz to obtain not only all previous results due to V.

Bonch-Bruевич, B. Halperin and M. Lax, A. Kane, L. Keldysh, B. Shklovsky and A. Efros, and J. Zittarz and J. Langer, but also new asymptotic behaviors of the density of states in the fluctuation region.

7. TRANSMISSION OF PARTICLES THROUGH A RANDOM-DISORDERED MEDIUM: 1979–1982

In the last years of his life I. M. Lifshitz paid great attention to the transmission of particles and waves through a disordered medium—the problem which is interesting in many respects.

The first work of the series [IV.11] dealt with the tunneling of a quantum particle through a macroscopically smooth potential barrier of finite thickness in which the particle undergoes elastic subbarrier scattering from random scatterers. The problem was to calculate the transparency σ_L of a layer of thickness L . Since the scattering is a subbarrier, even in a three-dimensional case the problem is almost one-dimensional. Furthermore, the problem is close to one-dimensional in the case where the layer is in the form of a bundle of thin filaments, and the observable transparency is given by

$$\sigma_L = M^{-1} \sum_{i=1}^M T_L^{(i)}$$

where M is the number of filaments and T_L is the transmission coefficient of one filament of length L . As $M \rightarrow \infty$, the observable transparency coincides with the mean transparency $\langle \sigma_L \rangle$ the contribution into which is due to improbable configurations with relatively high values of the transmission coefficient. Two essentially different physical situations are possible: (1) the resonance case, where the energy of a tunneling particle lies in the neighborhood of the discrete spectrum of disordered impurity centers, and (2) the nonresonance case, where the particle energy does not lie in the spectrum. In the resonance case, using the fluctuation ideology and the geometric description similar to that developed for studying the impurity band, I. M. Lifshitz considered the class of optimal configurations for which the transmission coefficient is close to unity and calculated the decrement of the mean transparency. In the nonresonance region, where the decrement is a smooth function of the parameters, the concentration expansion method was used.

The theory was then applied [IV.12] to study the explosion electron emission from a metal into a plasma when resonantly tunneling electrons contribute mainly to the emission.

The problems treated in this series are nonconventional mainly because of a rather complicated statistical nature of transparency. The transmission problem always involves two macroscopic dimensions: longitudinal (layer

thickness L) and transverse (cross-section area S). For a fixed layer thickness, the transparency is selfaveraged, i.e., becomes nonrandom, if the area S tends to infinity. It is shown in paper [IV.13], which considers these problems in detail, that for a bundle of filaments satisfying the relation

$$M = e^{qL}$$

and for large L the decrement of the observable transparence

$$\gamma_{\text{eff}} = -L^{-1} \ln \sigma_L$$

becomes nonrandom and depends on the parameter q as

$$\gamma_{\text{eff}} = \bar{\gamma} + \min_{\varphi(\xi) \leq q} \{\varphi(\xi) - \xi\}$$

Here $\bar{\gamma}$ is the self-averaged transmission coefficient of a single filament, and the function $\varphi(\xi)$ describes the probability density $P(\xi) = A \exp[-L\varphi(\xi)]$ of fluctuations $\xi = \bar{\gamma} + L^{-1} \ln T_L$ of the coefficient. Thus, the paper thoroughly considered, for the first time, how finite dimensions of a sample influence the statistical properties of its physical characteristics.

The problems just mentioned are now being extensively developed. A number of papers have appeared which deal with various aspects of the phenomena occurring on particle transmission through a disordered layer (these phenomena are of interest for specialists in solid state physics, optics, and radio-physics).

Lifshitz's ideas and works have played an important role in many fields of the physics of condensed state and have been generally acknowledged. We believe, nevertheless, that he exercised a special influence on the development of the theory of disordered systems. I. M. Lifshitz was, undoubtedly, one of the founders of the modern theory of disordered systems, and enormous progress in the theory is, for the substantial part, caused by his ideas and enthusiasm. He pioneered research in several directions of the theory, which are now being extensively developed. This is mainly due to a remarkable feature of his scientific activities: not only did his papers contain interesting ideas and results, not only did they present new effective methods, but they also formulated programs for studying various interrelated problems and outlined the ways to realize these programs.

At present, the physics of disordered systems possesses profound general theoretical concepts and a well-elaborated set of methods (see, e.g., the monograph by Lifshitz *et al.* [1.3]) a large number of different, sometimes unexpected, experimental results, and a rapidly growing field of applications. Although the theory of disordered systems, in its present form, is the fruit of international cooperation of scholars, Ilya Mikhailovich Lifshitz was, undoubtedly, one of the most eminent scientists who turned the theory into a vast and important branch of modern theoretical physics.