The Physics of Condensed Matter at Trieste

by John M. Ziman, F.R.S.

[1976]

Since about 40 per cent of the research activity in modern physics is concerned with the physics of solids and liquids, it was natural that these subjects should form a major part of the programme of the International Centre for Theoretical Physics at Trieste, from an early stage. For nearly ten years now, there have been advanced courses of study ("Winter Colleges") and Research Workshops at the ICTP for participants from both developing countries and the major advanced industrial nations.

From a scientific point of view, the title "Solid State Physics" is somewhat too narrow to describe this activity, since the affinity between the liquid and solid states as phases of "condensed matter" is itself of the greatest theoretical importance. It must also be recognized that this discipline, as practiced in many academic departments of physics, may be indistinguishable from what is done in the name of metallurgy, materials science, crystallography, chemical physics or physical chemistry. One of the important features of the ICTP programme in Condensed Matter Physics is that we do not draw hard and fast lines around the subject, but recognize that Nature knows better than academic administrators the natural intellectual boundaries of research and teaching.

In the same spirit, we have taken the view that there should be no hard and fast line between the formal analysis of mathematical theory and the techniques of observation and experiment. On the whole, the physics of condensed matter is not a heavily capitalized "Big Science", although the basic instrumentation of electron microscopy, spectrometry, etc., is not always cheap. There still remain many fields in which quite simple and unsophisticated apparatus may still give valuable scientific results, thus making it a very important subject for research in the universities and research institutions of developing countries.

But the subject is also very well developed theoretically with a deep and sophisticated literature involving, at times, very advanced mathematical concepts. It is extremely important, therefore, for the experimental physicist embarking on research in this field to be well informed concerning the latest theories and their interpretation. The physical and chemical phenomena that might be observed in quite a small and simple sample of condensed matter in the crystalline, glassy or liquid state are so diverse that their observation can be valuable to science only if guided by a strong theoretical and quantitative discipline.

The essence of the Winter College programme, therefore, has been to provide this sort of background over a fairly wide field, not only for professional theoretical physicists, but also for experimentalists in the same branches of the subject. It would, of course, be

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preferable also to have large scale experimental facilities at the Centre for training and demonstration in the various techniques of solid state physics, but this is quite out of the question under the present circumstances.

The Research Workshop programme has a rather different purpose, being the occasion for advanced research work by more experienced theoretical solid state physicists from the developing countries in close collaboration with senior scientists, coming to Trieste for a few months each year. At the beginning of this programme, it must be admitted that we found only a small number of solid state theorists in the developing countries competent to take part in research at this level, and were somewhat disappointed at the standard that was achieved. But these standards have improved rapidly during the last few years, and the research publications coming from Trieste constitute a valuable contribution to the world scientific literature on the subject.

In connection with the planning of the programme, the members of the Condensed Matter Advisory Committee have now had the opportunity to travel to many countries and are personally acquainted with the leading research workers in the subject in all the developing countries in all regions of the world. It has been a particular pleasure to notice the growth to maturity of a number of individual scientists and research groups which are now essentially "self-winding" and highly regarded in the field.

Another important characteristic of condensed matter physics is that it spreads over the whole range, from the purest and most fundamental topics, such as the superfluidity of the various isotopes of liquid helium, to very practical problems, such as the mechanical properties of engineering materials. To recognize the importance of this branch of physics in modern technology, we only have to point to the transistor, and the whole industry of solid state electronics that has come from it.

But condensed matter physics has innumerable other applications of growing importance — for example, long distance communication systems based upon optical transmission through glass fibres, or entirely new magnetic and structural materials such as glassy metals. Although we do not think it is the place of the ICTP to provide advanced training in practical technologies, we have always taken the view that the connections between pure science and its applications should not be neglected or obscured. In all our programmes, therefore, we have tried not only to give a sound theoretical background for the applied research worker but also an introduction to the most exciting new applications of the subject for the benefit of the more academic theoreticians.

We believe that this breadth of vision is extremely important for a scientist in a developing country, who may be almost the sole source of intellectual authority and technical knowledge over quite a large field of modern science and technology, and may feel a very serious responsibility to bring his research work to the aid of economic and industrial developments in his country. And in writing for the *Bulletin* of the International Atomic Energy Agency, I scarcely need to point out that a very high proportion of the research and development work associated with nuclear power is, in fact, concerned with the properties of materials in the very unusual and extreme conditions inside power reactors — a problem typically within the theoretical and experimental range of our subject.

Because of the very wide range of the science of condensed matter, we have not tried to keep up a continuous programme covering all aspects of the subject each year. Thus, the biennial Winter Colleges have dealt with specialized topics — Neutron Diffraction,

the properties of Imperfect Crystalline Solids, Surface Physics and Chemistry, the Interaction of Electro-magnetic Radiation with Matter, etc. In choosing topics for the programme on each occasion, we have been trying to look ahead towards subjects likely to be of technological or fundamental importance in the coming years. In the case of the Surface Science course, for example, there came together at the ICTP, for almost the first time in the world, leading experts from a diversity of aspects of the properties of surfaces to deal with topics as varied as low energy electron diffraction, surface waves, electro-chemical processes and even the properties of biological surfaces.

The lectures given at this Winter College are published by the IAEA in two volumes, forming a unique introduction to a science and technology that has implications to the tune of billions of dollars in connection with chemical corrosion, catalytic cracking of petroleum, static electrification, electronic communication systems, solar power production, etc., not to mention the great vitality of this subject as a rapidly growing branch of fundamental physics and chemistry.

From this description of the programme of the ICTP in condensed matter science, it will be seen that we have broken away from a narrow conception of theoretical physics and do not envisage the role of the Centre solely as a highly academic institution, whose benefits for mankind would not be expected to accrue for many, many years, as new basic theoretical concepts gradually permeated into industrial practice and technology. It has been our view throughout that fundamental research cannot live simply by its own internal objectives, but must, for its own health and for the value of what it produced, be integrated into the general framework of advanced technology, industry and economic development. It must be emphasized that we do not take this view simply for reasons of expediency, but because we believe that this is the genuine dynamic of the subject, which is deeply rooted, not only in the great intellectual revolutions of the modern quantum theory in the first half of the 20th century, but also in the discoveries made in the course of practical experience with metals and semiconductors, glasses and liquids. In our opinion, it is absolutely essential to convey to the participants in the Winter Colleges, and to those who take part with such personal enthusiasm in the Research Workshops at the Centre, this rich blend of hard fact and abstract theory, fundamental science and useful application, which is the true spirit of the subject. We think that this is particularly important as solid state physics and other related disciplines establish themselves in the new institutions of the developing countries and take up the tradition out of which the various disciplines have grown.

As I have already remarked, it is a feature of the Condensed Matter programme at the ICTP, that it is closely connected by personal links with programmes of a similar kind in various regions of the world. Thus, we have had close links, through the provision of lecturers, with several meetings of the Latin American Symposium for Solid State Physics, and with other specialized symposia in India and Pakistan. Thus, by contacts with individual scientists, both in Trieste and in their own countries, we have established something of an international community of solid state physicists, in a range of countries which are, to some extent, isolated from the main streams of science in the advanced countries. We regard the creation of this human network as of equal importance with the more formal scientific content of the lecture and research programme for which we are responsible.

On all the above remarks, I have used the personal plural to stand for the Solid State Advisory Committee, whose members are:

Professor G.F. Chiarotti,
Rome, Italy

Professor F. Gautier,
Strasbourg, France

Professor F. Garcia-Moliner,
Madrid, Spain

Professor L. Falicov,
Berkeley, California, USA

Professor N. March,
Imperial College, London, UK

Professor S. Lundqvist,
Göteborg, Sweden

Professor Dr. H.G. Reik,
Freiburg, Germany

Professor J. Ziman FRS
Bristol, UK

As chairman of that Committee, I should like to make it clear that we do not pretend to be a group that is representative of all branches of the subject or of all nations of the world. This is a *working* Committee, whose members have been chosen for the very simple virtue that they have been willing to commit themselves personally to a great deal of time and trouble in the affairs of the ICTP over a number of years. Of course, we do not pretend to have all the expertise that is needed to plan the programmes over such a wide field of physics, but we are, of course, able to draw in leading experts on every subject and have, indeed, had the most devoted and skilful aid of all those on whose services we have called.

The function of the Committee has been to plan in detail the practical activities of lectures and research, year by year at Trieste, and to take part as administrative organizers on the spot, when these activities are in progress. As a result of our long personal experience and commitment to the work of the Centre over nearly a decade, we have been able to maintain a consistent and integrated programme, which slowly develops and changes in response to the needs and growing maturity of condensed matter physics in the various countries of the world. We hope we may be given the resources to continue and improve this programme over a number of years in the future.

TOPICS OF WINTER COLLEGES

3 October to 16 December 1967
International Course on Theory of Condensed Matter.

12 January to 10 April 1970
Winter College on the Theory of Imperfect Crystalline Solids.

10 January to 15 April 1972
Winter College on Electrons in Crystalline Solids.

16 January to 10 April 1974
Winter College on Surface Science.

14 January to 26 March 1976.
Winter College on the Interaction of Radiation with Condensed Matter.