Physics in Belgium

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In Belgium, as in most countries, the universities play a central role in the development and organization of teaching and research in physics. However, as research has steadily required increasing financial and human support, progress in a number of areas has been largely stimulated by the existence of national research foundations. The sixties saw the explosion of the traditional group of four complete universities, located at Brussels, Ghent, Liège and Leuven, into a more regionalized ensemble. The free universities of Brussels and Leuven split into Dutch and French speaking entities and new universities were created in Antwerp, Hasselt, Mons and Namur. This centrifugal expansion had a positive impact on research in general and on physics in particular. The reason is partly to be found in the fact that the activities of newly created research groups could, in general, be coordinated satisfactorily with those of established institutions through the support given by national research foundations and even by government sponsored «concerted actions».

Most of physics research in Belgium is of a fundamental nature and industrial careers, specific to physicists, remain scarce. Applied research is, however, stimulated by a specialized national fund, by industrial initiatives and through the creation of industrial research units promoted by the universities. The general scope of research activities in physics is fairly well illustrated by the topics covered in the annual scientific meetings of the Belgian Physical Society. At these meetings, which are mainly concerned with national research activities, contributions are presented on subjects such as elementary particle physics, nuclear physics, atomic and molecular physics, plasma physics, solid state physics, astrophysics, biophysics and medical and applied physics.

Elementary Particle Physics

The experimental study of elementary particles was started in Belgium shortly after the second world war. At that time, a laboratory using the nuclear emulsion technique was created at the Université Libre de Bruxelles (ULB). This group made very valuable pioneering contributions to the detection and study of long lived, weakly decaying particles such as muons, π and K-mesons and hyperons. A first use of the then novel bubble chamber was made in 1961 with the creation of a national laboratory for the study of high energy physics, again located in Brussels, but which was no longer connected to any particular university. It was during the sixties that the first strongly decaying particles (resonances), were discovered and their production and decay properties determined. The national laboratory took part in this venture, mainly through the study of K^+-nucleon interactions produced in bubble chambers filled with liquid hydrogen or deuterium, exposed at the CERN 28 GeV accelerator.

Meanwhile, the laboratory of ULB continued to use the emulsion technique, concentrating on the study of hypernuclei (i.e. nuclei to which a Λ-hyperon is bound) produced in K-nucleus interactions. Interest in this subject led this group also to the use of heavy liquid bubble chambers. By the end of the sixties the Institut Interuniversitaire des Sciences Nucléaires had created a Belgian counter group based at CERN which worked in close collaboration with the group of the «Université Catholique de Louvain». The latter has, in addition, shown particular interest in the absorption and decay properties of low energy pions and muons as well as in the use of these particles in nuclear structure studies. Following the general trend of administrative decentralisation in Belgium, the national bubble chamber laboratory stopped its activities in 1971 with the creation of new groups at the university of Mons and at the new Flemish university of Brussels (VUB). The ULB and VUB laboratories soon associated into the Inter-University Institute for High Energies (IIHE) whose activities presently receive an additional support from research workers belonging to the Universitaire Instelling Antwerpen. These experimental groups developed a broad spectrum of research activities in the fields of weak and strong interactions. They participated in the CERN neutrino physics program (IIHE) and the strong interactions of various types of hadrons were investigated at the CERN, FNAL, Argonne, Serpukhov and Rutherford accelerators (IIHE, IISN-counter group, Mons). The neutrino experiments were particularly successful with the discovery of neutral currents and the observation and first life-time estimates of charmed particles. Although the experiments performed with hadrons have been mostly concentrating on the systematics of strong particle production and decay processes, the contributions made to the study of hidden charm ψ-states and of baryonium systems (S-and I-mesons) deserve a special mention. In parallel with the experimental research laboratories, theoretical particle physics groups developed in almost all universities, in particular those of Leuven, Liège, Louvain-la-Neuve, Mons and Brussels (ULB and VUB).

Nuclear Physics

In theoretical nuclear physics, the period 1961 to 1964 was marked by important work done at the University of Liège on the fundamentals of nuclear reaction theory. This line of research is now continued by microscopic calculations of nucleon-nucleus and the pion-nucleus interactions. At the University of Brussels a group of theoreticians has started research on the collective motion of the nucleus, and has also initiated studies on quasi-molecular structures, hypernuclei and heavy ion scattering. At the present time there are also theoretical nuclear physics groups in the universities of Ghent, Antwerp, Hasselt, Mons and at the Mol Nuclear Research Centre (SCK-CEN). Among the numerous subjects of interest let us mention Hartree-Fock and extended shell-model calculations, microscopic studies of deformed states in nuclei and of dissipation in unbound collective motion, alpha-nucleus interaction and application of group theoretical methods to nuclear spectroscopy.

Experimental nuclear physics grew out of the research of groups working mainly on radioactivity problems in almost all Belgian universities. With the foundation of SCK-CEN, neutrons became available for neutron physics research. This work is now continued at BR2 and also at the nearby linear electron accelerator of CBNM (Euratom)-Geel used for neutron production. At present, experimental low energy nuclear physics research is concentrated at the universities of Louvain-la-Neuve, Gent, Leuven and Liège. In Louvain-la-Neuve, the isochronous cyclotron is used for a wide spectrum of research activities. It is a variable energy machine (up to 80 MeV for protons) delivering several types of charged particles. A polarized neutron beam of 50 MeV obtained from deuteron scattering on a beryllium target is available also for medical research. A group of the KUL started at Louvain-la-Neuve a project for the separation on line of light isotopes (LISOL) to study nuclei that could not be reached before. At Liège, the Van de Graaff accelerator is used for nuclear reaction studies and there is an active group in beam foil spectroscopy. At the university of Ghent a 90 MeV linear electron accelerator is now in use mainly for the study of photonuclear reactions. A positron convertor is installed which allows monoenergetic photons to be obtained for use in the same reaction studies.

Atomic and Molecular Physics

It is convenient to classify the activities in atomic and molecular physics into two main parts which could be summarized as "spectroscopy" and "collisions". In the former we include classical optical spectroscopy, masers, lasers, optical pumping and magnetic studies. Collision physics, on the other hand, is concerned with the collision of atoms, electrons, ions and small molecules, both in single collision processes and in gases or plasmas; it also includes collisions of photons with atomic and molecular systems, as well as ionization and dissociation processes. Both branches of atomic and molecular physics are well represented in Belgium. Experimental spectroscopic studies, including laser spectroscopy and photo-electron spectroscopy, are carried out by several teams at the Universities of Brussels (ULB and VUB), Liège and Louvain-la-Neuve, and at the Institut d'Astrophysique de Cointe (Liège) and the Faculté Universitaire de Namur. These studies have provided a wealth of information concerning the structure and evolution of atomic and molecular states, among which various species are of great interest in astrophysics. Detailed ab-initio calculations of correlation energies, potential energy curves and transition probabilities are performed by theoretical groups at the Universities of Brussels and Liège and also at the Universitaire Instelling Antwerpen.

Important advances have also been made in Belgium during recent years in the rapidly developing field of atomic collisions. On the experimental side, the interaction of electrons and photons with atoms and molecules is studied in particular at the University of Liège, while atom (ion) — atom collisions (especially charge transfer reactions) are investigated at Louvain-la-Neuve by using an ingenious "merging beam" technique. Elaborate calculations, using the most sophisticated methods of quantum collision theory, are performed by the theoretical groups at the Universities of Brussels and Liège. Many of the atomic collision processes which are studied are not only of basic interest, but also play an important role in the development of controlled thermonuclear fusion.

Plasma Physics

During the 1950's plasma physics grew world-wide in importance due to the inception of the programmes in controlled thermonuclear research in the USA, USSR, UK and France and to the applications of the concepts of magneto-hydrodynamics in astrophysics. In our country the latter occurred mainly at the Institut d'Astrophysique of the University of Liège and also, during the past ten years, at the University of Antwerp where plasma stability is also theoretically investigated. In the late 1950's the well-known group for statistical mechanics headed by Professor Prigogine at the University of Brussels (ULB) enlarged its activity to include plasmas. Some important results were obtained: the Balescu-Lenard equation, the analogue of the Boltzmann equation for plasmas; the establishment of the quantum kinetic equation for plasmas, the kinetic equations for inhomogeneous and for unstable plasmas, and the theory of transport cœfficients.

Activity in the field of waves in plasmas was started in 1960 at the Ecole Royale Militaire — Koninklijke Militaire School (ERM-KMS) in Brussels concentrating during that decade on electron waves in bounded plasmas. In 1969 the Association "Euratom-Belgian State" for controlled thermonuclear fusion and plasma physics was established comprising the Laboratory of Plasma Physica of ERM-KMS on the one hand and the Plasma Group of the ULB on the other. The emphasis of the work at ERM-KMS was first on a systematic theoretical and experimental investigation of waves in the "hot plasma-magneto ionic" domain leading to new resonances and to a better understanding of the properties, including non-linear phenomena, of waves at various characteristic frequencies.

Since 1976, ERASMUS, a university scale tokamak at ERM has shown that bona fide tokamak discharges can be obtained at the small aspect ratios which will characterize the forthcoming large Joint European Torus (JET). The basic properties of magnetosonic resonances and their damping mechanisms in the ion cyclotron range are being investigated on ERASMUS with a view to the use of radio-frequency heating to thermonuclear temperatures of magnetically confined plasmas. Heating experiments at high RF power have been initiated and encouraging results obtained.

At ULB the kinetic theory of relativistic plasmas with a covariant formulation of statistical mechanics, was given much attention whereas in recent years, an important effort has been devoted to plasma-laser light interactions and to fusion by lasers including non-linearities, parametric instabilities and transport cœfficients. Finally, various other activities including electrical discharge physics, plasma spectroscopy, plasma theory and plasma chemistry are being conducted in other university laboratories: Université Libre de Bruxelles, Rijks-universiteit Gent, Université Catholique de Louvain, Katholieke Universiteit de Leuven and Université de Mons.

Solid State Physics

Solid state physics research in Belgium has followed the general international trend, the 1930's showing rather incoherent work in all universities on some properties of condensed matter. It was not before the late 1940's that the foundations of actual solid state laboratories were laid. If one looks back to those early developments, it strikes the eye that a few particular disciplines acted as channels. It was from a tradition of descriptive mineralogy that in the University of Gent, the physical approach to crystal growth and to the relation between physical properties and crystal imperfections, such as point defects and dislocations, were introduced. It was also via mineralogy that in Liège a laboratory for crystallographic structure investigations by X-rays was developed. In Leuven the introduction of cryogenics in Belgium opened a way to solid state research via the study of various phenomena, such as adsorption on thin films, electrical conductivity in semiconductors and alloys, superconductivity and magnetic resonance. Last but not least it should be noted that in the 1940's and 1950's quantum theory more and more proved its great merits for understanding the solid state in that it could not only describe simple atomic systems but also the complex many-body phenomena displayed in the comprehensive range of physical properties.

At Brussels, this development was pioneered in conjunction with statistical mechanics giving rise to theoretical and experimental developments in various directions: phase transitions, dielectrics, spin dynamics, solid state NMR, superconductivity, one- and two-dimensional systems.

In such a brief review it is impossible to sketch in any details the rapid and multilateral growth of solid state physics research in Belgium during the late 1950's and the 1960's. But, by way of example, it may be permitted to single out the development of one particular field of research, namely the imaging of crystal imperfections. Ghent was the first place in Belgium to recognize the importance of studying structural defects in solids. Later on it stimulated research teams in Mol and Antwerp to play a pioneering part in the use of transmission electron microscopy as a powerful tool for the study of dislocations, stacking faults, antiphase boundaries, etc. This line of research is continued nowadays on a frontier level by applying high resolution techniques, enabling defect imaging and analysis to be made down to the scale of atomic distances.

In the meantime, Belgian research has, of course, made important progress in many other branches of solid state physics as well. Nowadays virtually all relevant subdivisions of that field are touched upon by one or more Belgian laboratories. A rather arbitrary enumeration of the main themes may evoke the range of these activities: structure and defects in crystals; amorphous and polymeric materials; mechanical and acoustical properties; lattice dynamics; phase equilibria and transitions; atomic diffusion; surfaces and interfaces; thin films; electronic structure; electrical, magnetic, dielectric and optical properties; electron states, polarons, electronic transport; impurity and defect levels, Kondo alloys; positron annihilation; superconductivity and Josephson tunnelling; magnetic structure; magnetic resonance and relaxation; Mossbauer effect... Both experimental and theoretical work on these themes has developed not only in the universities but also in a few industrial research laboratories and in multidisciplinary research institutes such as SCK/CEN, Mol, often acting as a meeting point for scientific cooperation. This expansion in solid state physics research was further encouraged by various kinds of governmental incentives. The most striking results of such a support were the funding of a High Voltage Electron Microscopy Laboratory in Antwerp (1972) and the creation of projects such as ESIS (Electron Studies in Solids, Antwerp and Liège, 1973) and IRIS (Institute for Research in Interface Science, Mons and Namur, 1977) uniting the efforts of tens of Belgian and foreign solid state physicists. These projects have already achieved considerable progress in their respective fields.

Astronomy

Until 1930, research in astronomy was basically oriented towards positional astronomy, determination of time geodesy and cosmology (G. Lemaître). Although the Royal Observatory has acquired many large and sophisticated instruments, a major part of data acquisition can now be obtained from the European Southern Observatory (ESO) facilities in Chili. The Royal Observatory concentrates its present activities on such topics as: the determination of time, the earth's rotation, geodynamical observations, the photographic discovery of comets and small planets (see e.g. the comet «Arend-Roland»), solar radioastronomy, use of the Lyot-filter for solar photography, cool stars, stellar clusters, meteorology, the earth's magnetic field...

Astrophysical research at the Liège University was started in 1932 through the development of a molecular optics laboratory which inspired Paul Swings to compare the molecular laboratory spectra with the spectra of cool stars. This study led to the discovery of the first interstellar molecule (CH). Other spectroscopic research was concentrated on the UV spectra of multiple ionised atoms, rotational spectra of molecules excited by solar radiation in cometary tails, forbidden transitions of highly ionised metals in hot stars, spectroscopic research in the IR wavelength region. The Liège school of theoretical astrophysics continues its stellar studies on stability, evolution, dynamics, relativity and magnetohydrodynamics. High resolution IR spectra of the sun are obtained. This work has been extended towards the entire spectral region which is observable from the earth, resulting in the widely used spectral solar atlas. Moreover, basic work has also been performed on the determination of solar abundances.

The University at Brussels (ULB) has made significant contributions to the theory of galactical dynamics and has made important discoveries in the field of nuclear reactions in stellar interiors. The younger astrophysical institute in Brussels (VUB) has been much inspired by certain representatives of the famous Dutch school, and has made basic contributions to the study of the evolution of binary systems, Röntgen astrophysics, mass-loss in binaries, stellar wind, magnetic stars and spectral line formation. The X-ray spectrum in the range 1-20 Å has been investigated in the institute at Mons. In Louvain-la-Neuve (UCL) the sprit of the work of Georges Lemaître has been preserved by his successors. The institute of Leuven (KUL) nowadays concentrates its investigations on variable stars and stellar oscillations. General relativity and magnetohydrodynamics are topics which are investigated in Antwerp. Finally it has to be mentioned that the era of space research has stimulated many institutes to concentrate their efforts on the study of X and UV radiation.

Biophysics

The entrance of biophysics into the Belgian scientific community can be related to the foundation of the Belgian Biophysical Society in 1967. Research in biophysics is now performed in several universities (the two Brussels universities, Antwerp, Leuven and Liège) on subjects such as: the physical and physical-chemical characterization of biopolymers using light-scattering and hydrodynamical methods; the application of fast reaction and fluctuation techniques in biological systems; studies on the mechanism of photosensitization of biological systems; characterization of muscle proteins; study of the primary reactions of photosynthesis and physical chemical studies of membranes and membrane model systems.

Applied Physics

Notwithstanding the fact that Belgian universities have dedicated most of their efforts to fundamental physics, from 1946 onwards, experiments of an applied nature have been carried out on: optics;

acoustics; thermal conductivity; molecular and electronics spectroscopy; analysis by nuclear reactions, detection systems used on board research satellites such as TD1 and Météostat. New projects in the latter field are in the programme. To keep or improve a high quality technological level, several Belgian industrial companies are running a research centre. Using the tools of modern physics, metallurgy, electronics, chemistry, ... scientists and engineers investigate and develop new and better products. Several applied physical issues are noteworthy: research on electrophotography for reproduction, applied optics for more precise measuring and detection systems, vacuum evaporation and sputter techniques for an improved thin and thick film technology, surface and structure analysis resulting in better metal and conductor properties and in a better understanding of the physio-chemical suface condition.

Teaching

All the research activities described above are believed to have an essential influence on the quality of university teaching. A large fraction of these research disciplines are now part of the regular university curriculum for students in physics, thus not only contributing to the further development of fundamental and industrial research, but also to the improvement of the national level of education and culture.

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