Personalia

PETR LEONIDOVICH KAPITZA

(On the occasion of his seventieth birthday)

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THE prominent Soviet physicist Petr Leonidovich Kapitza was born in Kronstadt on June 26 (Julian calendar), 1894. He received his higher education at the Petrograd Polytechnical Institute, graduating from the school of electro-mechanics in 1918. While still a student, he attracted the attention of A. F. Ioffe, who interested him in scientific work and after graduation recruited him for his department. At that time the Soviet Government was sending many young scientists to study abroad. In 1921, Kapitza was sent on such a mission to England, where he worked under E. Rutherford in the Cavendish Laboratory, Cambridge University.

In 1928 Kapitza obtained his doctorate in physics and mathematics; in 1929 he was elected corresponding member of the Academy of Sciences of the USSR, and in 1939 was admitted to full membership.

Early in his scientific career, Kapitza, jointly with N. N. Semenov, proposed a new method of determining the atomic magnetic moment, using the interaction of the atomic beam with an inhomogeneous magnetic field. In 1922, he and Semenov published an article in the Journal of the Russian Physicochemical Society entitled "On the Possibility of Experimental Determination of the Magnetic Moment of an Atom," describing the appropriate experimental procedure. As everyone knows, this method was later applied by Stern and Gerlach. At the Cavendish Laboratory, Kapitza began to study the properties of alpha particles, in particular the determination of their momentum. With this end in view, he proposed a method in which particles in the Wilson cloud chamber were to be deflected in a magnetic field. However, to deflect alpha particles, which have a large mass, greater magnetic field strengths were needed than could be obtained with the aid of electromagnets, which at that time were the only known source of strong magnetic fields. To obtain magnetic fields of the strength he required, Kapitza evolved an entirely new method, that of sending currents of up to 10,000 A in 0.01 sec through an iron-free solenoid with relatively few turns. Using as his source a low-capacity storage battery he had designed, he obtained a field of about 100,000 Oe in a space of about 2 cm^3. He then replaced the storage battery which fed the solenoid by a special motor-generator. In this setup, the energy needed to create the magnetic field was accumulated as kinetic energy of the generator rotor which

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was coupled to the solenoid after the driving motor was disconnected. Using this method, Kapitza was able to obtain fields of up to 500,000 Oe, thus increasing by almost an order of magnitude the fields obtainable with the largest electromagnets.

He published the results of his work on producing pulsed magnetic fields in the Proceedings of the Royal Society in 1924. In this paper, he analyzed in detail various methods of creating pulsed magnetic fields, and also examined the possibility of using special transformers and high capacitance high-voltage capacitor banks as sources for the solenoid. It should be noted that, owing to improved-quality capacitors, the latter method is now widely applied, pulsed setups of this type being frequently used in various physical experiments.

When he first began to develop his new method of obtaining magnetic fields, Kapitza planned to use it for nuclear physics experiments; but his method actually had far wider possibilities and became an important tool in studying the properties of solids, particularly metals. This prompted Kapitza to make an extensive study of the properties of solids in pulsed magnetic fields. In a series of experiments of fundamental importance, he investigated the variation of resistivity with magnetic field in most metals and several semiconductors. He also evolved new automatic methods of measuring resistivity which were suitable for work in pulsed magnetic fields. These experiments allowed him to establish that in most metals resistivity increases linearly with the magnetic field. This phenomenon was subsequently called "Kapitza's linear law."

For a long time, the linear increase in resistivity remained one of the most puzzling properties of metals, and even in 1957 it was still regarded as an indication of lack of agreement between theory and experiment. Particularly puzzling was the linear increase in resistivity of the monovalent metals Cu, Ag, and Au, in whose case dependence of resistivity on the magnetic field should have given a curve with a saturation point. It is only recently that an explanation has been found of Kapitza's linear law. It appears that this law results from the unique dynamics of electron conductivity in metals. In a number of cases, this leads to a quadratic increase in resistivity for some directions of the field relative to the crystal axes, and to saturation for other directions; averaging, even over small angle intervals, can give a linear change of resistivity with change in the field.

Using the super-strong pulsed-field methods he had evolved, Kapitza also studied the magnetic properties of metals; in particular, he thoroughly investigated the susceptibility and magnetostriction of diamagnets and paramagnets. It should be noted that this was the first work done on the striction of nonferromagnetic metals.

Simultaneously with intensive experimental work, Kapitza studied the theoretical aspect of such questions as the reflection of electrons from standing light waves, and published in 1933 an article on this subject which he co-authored with Dirac.

Kapitza's fruitful scientific work in England was held in high esteem by English scientists, including the outstanding physicist Rutherford. From 1924 to 1932 Kapitza served as deputy director of the Cavendish Laboratory, whose director at that time was Rutherford. In 1929 he was elected member of the Royal Society, and from 1930 to 1934 he was director of the Royal Society Mond Laboratory in Cambridge University.

On his return to the Soviet Union in 1935, Kapitza organized in Moscow the Institute of Physics Problems, whose director he still is today. He continued his investigations of super-strong fields. Jointly with P. G. Strelkov and É. Laurman, he published a paper on the Zeeman and Paschen-Back effects in fields of up to 320 kOe.

Since the degree of influence of a magnetic field on metals is measured by the ratio of magnetic to thermal energy, Kapitza found it necessary, in order to investigate more accurately the changes in resistivity of metals with the magnetic field, to make measurements at the low temperatures of liquid hydrogen and liquid helium. Kapitza became interested in methods of liquefying hydrogen and helium while still in England; he now created a new type of liquefier enabling industrial hydrogen to be liquefied without prior purification. He investigated thoroughly the possibility of using piston and rotary gas-expansion machines for liquefying helium. This study enabled him to change radically the methods then in use and to develop an entirely new type of helium liquefiers. His work resulted in greatly increasing the productivity of helium liquefying apparatus and considerably simplifying the techniques of working with helium. Also, new prospects were opened up for experimentation in the range of liquid helium temperatures. Kapitza not only developed a new liquefying cycle using piston expanders, but also solved a very difficult experimental problem by building liquefying apparatus with a piston expander working at 10°K. At such temperatures, the machine cannot be lubricated in the usual way, so Kapitza invented so-called "gas-lubrication," leaving a small annular gap between the piston and the cylinder. It must be noted that the helium expansion liquefying apparatus designed by Kapitza served as the prototype for all modern liquefiers, while the double-expander apparatus he has constructed recently makes it possible to obtain dozens of liters of liquid helium per hour.

Once he became interested in the technique of liquefying helium and hydrogen, Kapitza discovered that the air liquefiers used for preliminary cooling in the liquefaction of both hydrogen and helium were far from perfect. He designed a new type of liquiefiers, working at low pressure, using a rotary rather than a piston expander. In designing this new apparatus, Kapitza solved a number of complex physical and technical problems, which necessitated a study of the work of high-speed turbine expanders. The rotary machine constructed by Kapitza had high efficiency. This apparatus made it possible to develop low-pressure liquefying setups in which piston compressors were replaced by compact rotary compressors, also with high efficiency. Of special importance is the use of these expanders in large scale production of industrial oxygen gas. Kapitza's turbine expander led to a review of the principles of the cooling cycles used to liquefy and separate gases, the result being to alter the entire trend of development of world techniques for obtaining oxygen in large quantities.

One of Kapitza's major scientific contributions was his discovery of the superfluidity of liquid helium. Having become interested in the amazing properties of liquid helium, he came to the conclusion that the so-called "super-heat-conductivity" of liquid helium at T = 2.19°K, discovered at Leyden, is in reality superfluidity, i.e., the disappearance of viscosity. In a series of supremely elegant experiments, Kapitza demonstrated that below the critical temperature the viscosity of helium virtually drops to zero. He then proceeded to investigate thoroughly the properties of liquid helium in this new state which he discovered. In particular, he demonstrated convincingly that in the temperature range below 2.19°K liquid helium has two components, one superfluid and the other normal, the superfluid component having zero entropy, in other words, in a sense being a fluid at absolute zero temperature. These experiments of Kapitza's resulted in the quantum theory of liquid helium; this theory was developed by L. D. Landau, and led to considerable further experimentation, resulting, in particular, in the discovery of the "second sound" by Kapitza's student V. P. Peshkov.

While studying the properties of liquid helium in the superfluid state, Kapitza discovered that a temperature discontinuity obtains at the solid-liquid helium boundary; this phenomenon, now known in the literature as "Kapitza's discontinuity," has been only partially explained by Khalatnikov and is still being investigated by foreign and Soviet researchers.

Kapitza's experiments with superfluid helium were interrupted by the war. He spent the war in Kazan', where the Institute of Physics Problems of which he was the head had been transferred. During this period he directed and himself conducted a series of investigations which were of major importance for the country's defense, while also acting as the chief of the Main Administration of the Oxygen Industry and as chairman of the Administration's Scientific Council.

After the war, in the late Forties, Kapitza became interested in an entirely different field—high-power electronics. In a report which he wrote in 1952 and which later, in a revised version, appeared in book form in 1962 (and also as an article in Uspekhi Fizicheskikh Nauk), he set forth both a general theory of magnetron type electronic devices and the first experimental results obtained by using a continuous magnetron oscillator or planotron, which he had designed. In this work Kapitza shows himself to be an able theoretician. By using a clever mathematical method (that of averaging in time), he overcame the difficulties occasioned by the complex character of the movement of electrons in super-high-power magnetron oscillators and ascertained the basic characteristics of such devices. Moreover, alongside with a general theoretical study, Kapitza conducted experiments using the planotron, which enabled him not only to check theory against experimental findings but also to develop the theory in the right direction.

In his book Kapitza, in discussing the problems of high-power electronics, does not confine himself to the existing electronic devices and means of using them, but analyzes their latent physical possibilities and the technical problems which they might be capable of solving.

Kapitza's "High-Power Electronics" was the first in a series of publications on work done in his laboratory, which he edited and to which he also contributed. The third volume in this series, which appeared in June 1964, contained an article by P. L. Kapitza, S. I. Filimonov and S. P. Kapitza entitled "Theory of Electronic Processes in the Continuous Magnetron Oscillator." This article, which is the culmination of Kapitza's major 1952 study, contains a theoretical analysis of the difficulties encountered in the construction of high-power continuous magnetron oscillators and demonstrates that these difficulties can be overcome in a device which the authors call a double-row nigotron. In this device, the anode and cathode have periodic structure (two rows of circuits in each) and are inserted into a cylindrical cavity; in operation, the H_{010} mode is excited in the cavity and the field in the slots oscillates in phase (0 oscillations, in contrast to the π oscillations in magnetrons).

In addition to his work in electronics, Kapitza took up a number of related questions. For example, in 1954-55 he became interested in ball lightning, and put forward a hypothesis regarding its formation. The properties of ball lightning hardest to explain are its long lifetime and the great amount of energy accumulated in it. Assuming that the sources of energy contained in ball lightning were the centimeter-band electromagnetic oscillations which occur during a normal lightning discharge, Kapitza examined the possibility of the occurrence of standing waves being reflected from the earth's surface. The antinodes of such standing waves might cause the formation of ball lightning. Although a number of details have not yet been clarified, this study of Kapitza's has attracted attention both in the USSR and abroad, since it is apparently one of the few hypotheses extant offering a logical explanation of this mysterious natural phenomenon.

Lack of space prevents us from expatiating on other interesting investigations carried out by Kapitza, such as his work on the wave flow of thin layers of viscous liquids, motion of a pendulum with a vibrating suspension, heat conductivity and diffusion in liquid media, the hydrodynamic theory of lubrication, etc.

Before concluding this brief survey of Kapitza's scientific work, we must draw attention to the great influence he has exerted on the development of experimental methods. He has invented a great many extremely ingenious methods of experimentation and means of measuring various physical quantities. These include methods of measuring the susceptibility in pulsed magnetic fields, methods of growing single crystals, in particular bismuth crystals, the invention of an automatic photoelectric pantograph which makes it possible to enlarge oscillograms several times virtually without increasing the width of the line, metal containers for storing liquid helium, invention of the oxymeter, a device for measuring the oxygen content of gases, a method of balancing the rotors of turbine expanders, an instrument for measuring the intensity of short-wave radiation, and many more.

It is characteristic of Kapitza that when he takes up a branch of physics or technology to which he is a newcomer, he contributes so much to the knowledge of the subject that its further development takes an entirely new turn. This happened when, leaving nuclear physics, Kapitza began to study the physics of solids and investigated super-strong pulsed fields; it also happened when, becoming interested in liquefying techniques, he invented not only an entirely new method for liquefying helium but also evolved various new liquefiers of oxygen, hydrogen, and helium; and it happened again when, on deciding to look into the properties of liquid helium, he discovered superfluidity and made a thorough study of the properties of superfluid helium; it would seem that something of the same sort is happening now, for having begun to investigate the generation of short radio waves he has laid the groundwork for new departures in this interesting branch of physics.

In addition to intensive research, Kapitza has been very active as a teacher. He began to teach in 1919, when he lectured on physics and mechanics in the Leningrad Polytechnical Institute. He continued teaching while in England; from 1930 to 1934 he was research professor at the London Royal Society. In 1939, he organized the department of physics of low temperatures at the Moscow State University, and introduced practical work sessions at which students were given an opportunity to conduct experiments at low temperatures. It is worth noting that this was the first place in the world where undergraduates were allowed to work with liquid helium. Kapitza was also one of the prime movers in the establishment of a special physico-technical school at the Moscow University. This school was opened in 1946 and was soon transformed into the Moscow Physico-technical Institute (MFTI). From 1946 to 1949 Kapitza was head of the department of general and experimental physics of MFTI and lectured on general physics. He is now head of the department of physics of low temperatures at the Institute and chairman of its co-ordinating council. He has a large number of students, including a good many foreign physicists.

The Institute of Physics Problems, from its inception, has maintained a scientific seminar, conducted by Kapitza, which is famous throughout the country. Both young scientists in training and well-known Soviet physicists present papers at this seminar. It is a logical continuation of the scientific seminar which Kapitza organized in England and which was attended by such eminent physicists as Bohr, Dirac, Ehrenfest, and Cockcroft. Kapitza still preserves the records of these gatherings, which form an interesting chapter in the annals of physics.

While carrying on his scientific work, Kapitza has always been active in public affairs. From 1955 to 1962 he served as chairman of the scientific council on the physics of low temperatures, which he himself organized. For a number of years he has been a member of the Presidium of the Academy of Sciences of the USSR and editor in chief of the Journal of Experimental and Theoretical Physics. He is a member of the Soviet National Committee of the Pugwash Movement of Scientists for Peace and Disarmament. He has published a number of articles in the general press on scientific subjects and on issues of public interest.

The Government has proved highly appreciative of Kapitza's services: he has been awarded the Order of the Red Banner, three Lenin Medals, and the title of Hero of Socialist Labor. He was twice given a State prize for his work.

Kapitza is a member of nearly twenty academies and learned societies throughout the world, including the Royal Society of Great Britain, the National Academy of the United States, the Indian Academy of Sciences, and the Academy of Sciences of Denmark. His work is known the world over and various countries have awarded honorary prizes to him.

Petr Leonidovich Kapitza is approaching his seventieth birthday full of strength and creative ideas. His energy is such that many young scientists might well envy him. Even so, it is only because of his extraordinary ability of planning his time that he is able, despite his great load of pedagogical, organizational and public activities, to work every day in his laboratory. We heartily wish him further great successes in all his many and varied undertakings.

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