C
Iℓ6uZp

ALMY

A CENTURY OF PHYSICS AT THE UNIVERSITY OF ILLINOIS, 1868-1968

A CENTURY OF PHYSICS

AT THE UNIVERSITY OF ILLINOIS

1868 - 1968

A talk given before the History of Science Society
in December, 1967, during the
Centennial Year of the University of Illinois

Edited in 1973 with minor changes and additions.

G. M. ALMY

ENGINEERING LIBRARY

C
Il6uZp Engin

Table of Contents

Page

Foreword Written in 1973 i

First Period in the History of the Department, 1868-1896 .. 1
Stillman Williams Robinson 1
Selim Hobart Peabody 3
Samuel Wesley Stratton 5
Daniel William Shea 7

Second Period in the History of the Department, 1896-1929 . 8
Albert Pruden Carman 8
Jakob Kunz 11
Floyd Rowe Watson 12

Third Period in the First Century of the Department, 1929-1968 15
Francis Wheeler Loomis 15
Nuclear and Particle Physics at Illinois 17
The War Years and Reconstruction 24
Solid State and Low Temperature Physics 27
Supporting Staff and Services 30
The Problem of Space for the Physics Department 31
Numbers of Graduates in Physics at Illinois 33
Number of Illinois Ph.D. Degrees in Physics Through 1972 35

Foreword Written in 1973

This manuscript was written in 1967-68 following an invitation from the University of Illinois History of Science Society to give a talk on the history of the Physics Department. The talk was one of a series on University science departments, to mark the Centennial Year of the University. For the purpose of the talk the early history of the Department was stressed. For five years since that occasion it has been my intention to revise the manuscript to include a fuller account of the great expansion and accomplishments of the Department in recent years. Events, however, have outpaced my efforts and I only fall further behind. Hence I have decided to print some copies of the 1968 manuscript with only a few changes and additions, mainly in the form of footnotes.

The history of the Physics Department can be divided into three periods. Each has it distinctive characteristics. The first period began soon after the University was founded in 1868 and extended through 28 years to 1896. The second period, 33 years, was the regime of Albert P. Carman, as Head, from 1896 to 1929. The third period began when F. Wheeler Loomis came to Illinois as Head, in 1929.

Physics at Illinois evolved in the College of Engineering. For the first period my chief source of information has been _A History of the College of Engineering, 1868 - 1945_, by Ira O. Baker and E. E. King. Professor Baker wrote of the early days from personal knowledge. He entered as a student of Civil Engineering, class of 1874, then joined the faculty and served for 48 years, until 1922. For 39 years he was Head of the Civil Engineering Department. For the second and third periods of departmental history I have depended mainly on departmental records, supplemented by my personal recollections and those of other old timers.

G. M. Almy

UNIVERSITY OF ILLINOIS LIBRARY AT URBANA-CHAMPAIGN

FIRST PERIOD IN THE HISTORY OF THE DEPARTMENT, 1868-1896

On March 11, 1868, the University was formally dedicated and John Milton Gregory was installed as Regent, as the chief executive officer was called until 1894. Fifty students were enrolled in that first spring term under a faculty of four, including the Regent.

In the Catalog and Circular of 1870-71 the work of the University is divided into four divisions although the faculties were not formally organized until 1878. The four divisions were Agriculture, Engineering, Literature and Science, and Natural Science. Instruction in Engineering began in 1870 and it included a course in physics. It was recognized from the beginning that a knowledge of physics was fundamental to the education of every engineer.

Physics was not organized as a separate department until 1889. During the first period, however, three remarkable men were at different times in charge of instruction in physics. Their names were Robinson, Peabody and Stratton.

Stillman Williams Robinson

On January 1, 1870 Stillman Robinson came to Illinois as Professor of Mechanical Science and Engineering. Robinson was born in Vermont in 1838. At age 17 he began four years of service as an apprentice mechanic. His experience led him to seek an education in mechanical engineering. In 1859, unable to find an institution offering such a course, he decided to study civil engineering at the University of Michigan. He set out on the 600-mile journey on foot, with eight dollars in his pocket, and arrived at Ann Arbor with $58, having plied his trade on the way. He was graduated in 1863, worked for the U.S. Lake Survey for a period and was Assistant Professor of Mining Engineering and Geodosy at Michigan for the three years before he came to Illinois at 1870. He was then 32 years old. He had published articles on a variety of engineering subjects and held patents on several inventions.

At Illinois Professor Robinson taught all of the technical courses in mechanical and mining engineering. In his first year he also introduced and taught a course in physics which continued to be one of his major interests. All of the engineers took the physics course in their third year. According to the 1872-73 catalog: "Physics has been amply provided for in the New Building (University Hall) by the appointment of a Physical Laboratory and Lecture Room to which the apparatus will be removed this summer ... In connection with the lectures, Silliman's Physics is used as a textbook; since many of the topics are more thoroughly discussed in other classes, special attention is paid to the portions remaining. The following are the main heads: Matter, Force, Motion. Properties and Laws of Solids, Fluids, and Liquids. Acoustics and Optics, with mathematical discussion of the undulations and instruments. Solar and Stellar Spectra, etc. Magnetism. Electricity. Chemical Physics is given in a special course of lectures".

Instruction in physics initially consisted of four recitation periods per week. Professor Robinson soon introduced, in addition, demonstration lectures and laboratory practice. In the lectures, to quote the 1874 catalog "Illustrative experiments (are performed) one evening each week in which the more costly apparatus is used before the whole class in such experiments as are difficult to perform, and which are most effective when prepared for an audience".

He did not shrink from the difficult demonstrations. One of them required an array of 200 wet chemical cells to produce sufficient electric current for his purpose. In another he set up an arrangement of prisms and lenses to display spectra which covered the wall of the lecture room, and he discussed the relation of the spectra to current theories of the physical constitution of the sun.

Laboratory practice was introduced in January, 1875. At that time, laboratory work in physics was offered in only two institutions in the United States, the Stevens Institute of Technology and the Massachusetts Institute of Technology where it was introduced in 1871 and 1873, respectively.

Professor Robinson distributed long-hand written descriptions of each experiment to the student the week before he performed the experiment. The students, it is reported by Baker, were intensely interested, put in two or three times the two hours allotted to do each experiment, and competed strongly in the preparation of reports, in respect to appearance, completeness and accuracy.

These efforts show that Robinson clearly believed that physics is something men do and not the content of the textbooks. Although he was an intensely practical man, he understood and applied mathematics and was, indeed, a leader among engineers of his day in this respect. Baker and King remark that a noted engineering handbook published about 1870 boldly asserted that higher mathematics was useless to an engineer. This statement greatly impressed the students and tended to alienate them from the essential mathematical and scientific preparation. But Professor Robinson's versatility, ability and enthusiasm in the constant and effective use of higher mathematics were very effective in leading the students to adopt the better ideals of an engineering education.

By 1878 four curricula in engineering had been established - mechanical, civil, mining, and architecture. The total engineering faculty consisted of three professors and three instructors. The student enrollment in engineering was 59; in the university it was 416. In February, 1878, Robinson was appointed the first Dean of the Engineering College, but in the same year he resigned to accept an appointment as Professor of Mechanical Engineering and Physics at Ohio State University. He has left a landmark on the Illinois campus. He designed and supervised the building of a tower clock for the Class of 1878. It was installed in University Hall and its mechanism now actuates the clock in the Illini Union tower.

Selim Hobart Peabody

In 1878 Selim Peabody came to the University as Professor of Mechanical Engineering and Physics. He had been a teacher of Physics for 25 years, most recently at Central High School in Chicago. Within two years, however, he was appointed Regent, in 1880, on the resignation of John Milton Gregory. For five more years Peabody continued to teach physics to the juniors, and hydraulics and resistance of materials to seniors in engineering. One interesting bit of evidence that he was on the job is a quotation from the Daily Illini in March, 1884, which is included in Roger Ebert's "An Illini Century": "The Regent showed some darkroom experiments on Thursday. The magic lantern was put in working order, but had not been lighted long before some defect in the burner transferred the fire to the tubing. Through that it traveled into the oxygen bag. The rubber burned in that gas until enough CO_2 was formed to burst the sack, when an explosion occurred. All were more or less frightened, although none would own it. No one was hurt. The hydrogen was not reached, or more serious results might have been expected". This is a nice bit of scientific reporting. And it is impressive, and alarming, that the Regent (or anyone) ever projected slides that required, for illumination, an apparatus for generating, storing, mixing and burning hydrogen and oxygen.

Now it is not to be expected that Regent Peabody made memorable contributions to physics, for, in addition to teaching two courses regularly, he had to run the University. His administration was not an easy one. A major problem was the finances. The enrollments were rising and the faculty was ambitious to expand the program. The General Assembly, though sometimes willing to appropriate money for buildings, was extremely reluctant to appropriate anything for faculty salaries and other instructional expenses of the University. It had been anticipated that the land-grant endowment would take care of these. After a hard campaign Regent Peabody and the Trustees secured, in 1881, the first small appropriation to be made for instructional costs.

Naturally, it was difficult to employ additional faculty under these circumstances. In Peabody's regime, 1880 to 1891, the faculty increased from 28 to 39 and the student enrollment approximately from 400 to 600.

Another effort by the Regent to secure additional resources has a familiar ring. He took an active role in securing in Washington the passage of bills in 1887 and 1890 which provided the first grants to Illinois in support of university research, in this case in Agriculture.

To top it all, the Regent, in this austere period, had almost no clerical help or office equipment. He conducted his official correspondence in long hand. He personally made out all student class cards at the beginning of each term and entered the grades on the record at the end. And last but not least in effort required, he brought about the change in name of the institution in 1885 from the Illinois Industrial University to the University of Illinois. The change was strongly supported by faculty and students and bitterly opposed in the General Assembly, especially in the Senate.

From 1885 to 1889 Theodore B. Comstock, Professor of Mining Engineering and Physics, was in charge of the work in physics. In the spring of 1889, a separate Department of Physics was established and Comstock was appointed Head. At the end of the summer vacation, however, he unexpectedly failed to return to the University. Regent Peabody asked S. W. Stratton, a young man who had been his undergraduate assistant in physics, to take charge of the new department, with the rank of Assistant. It was a surprising appointment, even in emergency, for Stratton had just accepted an appointment as Assistant in Architecture. But Peabody knew what he was doing for it turned out to be a really excellent appointment.

Samuel Wesley Stratton

Samuel Stratton was born in Litchfield, Illinois in 1861. He received a bachelor's degree in Mechanical Engineering at Illinois in 1886. From 1885 to 1889 he was a mathematics instructor in the University's preparatory school. As noted above, he was appointed Assistant in Architecture in 1889, but was transferred to be Head of the new Physics Department before he took up his duties in Architecture. He was 28 years old.

He was an immediate success in his new position. He was promoted to Assistant Professor of Physics in one year, and to Professor of Physics and Electrical Engineering in the following year. His great contribution was to expand the work in theoretical and applied electricity. In his second year, he announced in the Catalog of 1890-91 that the University was prepared to offer a full curriculum in electrical engineering. A year later, the entire ground floor of the east wing of University Hall had been made into an electrical laboratory, with a room for electrical measurements, a battery room, a dynamo room, a photometry room and a shop. The principal prime mover in the dynamo room was a 60-horsepower high-speed steam engine. Its din made impossible the use of the lecture room immediately above. Seven or eight direct and alternating current generators of differing design were also installed and connected to the steam engine through a jack shaft. Instruction and experimental work in electrical engineering was well underway. Electrical engineering remained a part of the Physics Department until it was given a separate departmental status in 1898.

Stratton's work in the Physics Department attracted the attention of the entire University, according to Professor Baker. Baker, in Civil Engineering, was setting up at the same time the first concrete-testing laboratory in the country, and happily breaking up blocks and cemented joints. His first laboratory was also located on the first floor of University Hall. Relief for other occupants, however, was not far away. Engineering Hall was completed a few years later, in 1894, and all of Engineering including Physics moved out of University Hall. The move could not have pleased the engineers any more than it did the literature and language faculty and students who were left behind.

Stratton in three years had given the work in physics new directions, new life and great momentum. In 1892, however, he was lured to the new University of Chicago where he began again as Assistant Professor and was promoted through the ranks to Professor. Nine years later, in 1901, he left Chicago to become the first Director of the National Bureau of Standards in Washington. He served in that capacity until 1923. He then became President of the Massachusetts Institute of Technology and, in 1930, Chairman of the M.I.T. Corporation. He died in 1931, at the age of 70, closing a career in which he had made basic and lasting contributions to the development of three universities and a great government laboratory.

Daniel William Shea

The first period in the history of the Physics Department closed with the short tenure of Daniel Shea. He came to Illinois in 1892 as Assistant Professor and Head of Department. He was promoted to Professor of Physics in 1894. He was the first professor on the faculty who had been educated to be a physicist, with AB and AM degrees from Harvard and Ph.D. degree from Berlin (1892). For the first time the Catalog in 1894 emphasized that one aim of the courses in physics was to prepare students to do research in physical science. But no degree program in physics as such was yet offered.

The faculty, consisting of Professor Shea and one instructor, must have been extremely busy with the general physics course and the seven or eight more specialized courses in electrical science and engineering. The latter had quickly become the most popular curriculum in engineering with 91 out of a total of 305 engineering students enrolled in it in 1894-95. In that year, the department also had the task of equipping its commodious new quarters on three floors of the new Engineering Hall, and moving from University Hall.

Early in 1896 Professor Shea resigned to become the first Professor of Physics at the Catholic University in Washington, D.C. So ended the first period in the history of the department.

It is easy to see from the early history how Physics was firmly fixed in the College of Engineering at Illinois. Robinson, the first Professor of Engineering, regarded physics as the foundation of engineering. He originated, developed and taught the physics course during his eight years at Illinois. Regent Peabody, also a Professor of Engineering, continued the emphasis on physics. Then Stratton in a great burst of energy established a full scale program in electrical engineering within the Physics Department, where it remained until 1898. Strong links between Physics and other departments in the College of Engineering have continued to this day.

SECOND PERIOD IN THE HISTORY OF THE DEPARTMENT, 1896 - 1929

Albert Pruden Carman

The second period was the 33-year regime of Albert Carman, from 1896 to 1929. Carman received a Ph.D. degree from Princeton in 1886, and had held faculty positions at Princeton, Purdue and Stanford. At Illinois, he had charge, for two years, of the Electrical Engineering program, which had been started six years earlier by Stratton, and which became a separate department in 1898 under Professor William Esty. Indeed, one of Professor Carman's first tasks was to supervise the purchase and installation of the equipment for the University's first lighting and power plant, the Boneyard Plant located in a building which is now a part of the Electrical Engineering Research Laboratory, near the Fire Department Station.

The faculty, program and facilities of the department were built up rapidly during the first part of Carman's headship. Prior to 1896 the faculty consisted of the professor and, at most, one or two instructors. By 1909, Carman had brought in five young Ph.D.'s in physics, at ages 27 to 34. They all continued in the department until their retirement or death in the 1930's. F. R. Watson came in 1899, W. F. Schulz in 1900, C. T. Knipp in 1903, E. H. Williams in 1907, and Jakob Kunz in 1909. Only one additional member joined the permanent faculty during the Carman period - R. F. Paton in 1922.

A major accomplishment in this early part of the Carman period was the completion in 1909 of the Physics Laboratory at Green and Matthews Streets (now the home of the Metallurgy and Mining Engineering Department). After extended discussion on need and proper location, and great efforts in Springfield, an appropriation of $250,000 was obtained in 1907, but only $220,000 was actually required to build the Laboratory. This worked out to be a cost of a little more than two dollars per square foot, less than 1/25 of the cost of a comparable building today. From the day the contract was let in 1908, the laboratory was built, occupied, and dedicated within a period of 17 months, a feat which was apparently not considered remarkable at the time, but would be amazing today.

The laboratory was really excellent for its day, thanks to the effort and thought that was put into its design, especially by Professors Carman and Knipp. While planning it they visited twenty physics laboratories in other universities.

The largest single task of the department then as now was instruction in introductory general physics. The two principal general courses given today are direct descendants of the two offered sixty years earlier. The faculty worked hard at teaching. They also wrote textbooks and laboratory manuals and published numerous articles on ingenious lecture demonstrations of physical phenomena.

Physics was not widely recognized as a vocation or profession before World War II, except in the schools and universities. Enrollments in advanced undergraduate courses at Illinois were typically 5 to 10. A major in physics, leading to a bachelor's degree in Engineering Physics, was not established until 1917. The first degree was granted in 1923. Only 15 degrees were awarded through June of 1929.

Graduate education and research in physics, however, was given substantial impetus by the completion of the new laboratory in 1909 and by the establishment of the Graduate School in 1908. The number of graduate students in physics rose from 10 in 1907 to 30 in 1928. The first two Ph.D. degrees were awarded in 1910 to E. B. Stephenson and E. H. Williams. Their respective thesis topics were Magnetic Properties of the Heusler Alloys and The Nature of Spark Discharges at Very Small Distances. Both were published in the Physical Review in September, 1910. By 1929, 36 students had earned the Ph.D. degree in physics. Some had been undergraduates at Illinois and other state universities but more of them came from the four-year colleges, including Knox, Carleton, De Pauw, Lawrence, and Albion.

In the early part of this period the graduate students were full-time instructors or assistants and had little time for research. The effect of research on teaching was already a hotly debated subject. In a bulletin on Academic and Industrial Efficiency, issued by the Carnegie Foundation for the Advancement of Teaching, academic efficiency apparently came off badly. At any rate, Professor Carman was moved in 1911 to make the following remarks in his annual report:

"We aim to advance the science of physics by instruction and investigation, but we also have the important and interesting duty of giving instruction to meet the needs of the University courses of study. This has suggested a conflict of interest to various writers and there have been many emphatic expressions of opinion that teaching is being neglected in our universities. I do not believe that we do poorer teaching because we have at heart the advancement of the science. In fact, when I think of one or two institutions, where investigations in physics have been distinctly discountenanced, and have seen the results on their instructors and classes, I feel that investigation has its inspiration even to elementary teaching. At Illinois, we have been putting heavy pressure on our instructors to be "productive". But we have not made enough allowance in teaching schedules, if we are to insist on productivity for advancement. In two cases this year, we nearly had nervous breakdowns from this policy. Hence, we shall ask for more help in the coming year. Live young men of 24 or 25 years will not work for $1000 or less per year and not have a chance for scholarly advancement...The larger University view must be considered in "efficiency"! Our instructors have not been and will not be idle, and a certain amount of time to work in physics will help in instruction, as well as yield results to science."

In the early twenties, Professor Carman secured approval, apparently over some opposition, to appoint graduate teaching assistants on a half-time basis to give them more time for research. The half-time salaries of $400 to $500 per year were hardly adequate for extensive participation in the legendary extracurricular activities of the roaring twenties.

Professor Carman made valiant but unsuccessful efforts to add to the faculty in the 1910 to 1920 decade. Apparently registrations in advanced physics courses did not justify new faculty positions, for he argued that the need for additional faculty should not be measured in terms of student credit hours but rather in terms of the fields which should be represented in a modern department.

The period from 1896 to World War I saw a revolution in many basic ideas of physics. X-rays, radioactivity, and the electron were discovered. Einstein developed the theory of relativity, and put forth the simple elegant explanation of the photo-electric effect in terms of the quantum theory of radiation which had been introduced by Planck. Rutherford established the nuclear atom by experiment and Bohr used it in his theory of atomic structure and spectral radiation. The development of physics at Illinois suffered somewhat from the fact that the faculty, assembled at the turn of the century, had been educated primarily in the old school in which the phenomena of matter and radiation had received their highest level of understanding and unification in terms of the theory of the luminiferous ether, in the works of such intellectual giants as Maxwell, Hertz, Kelvin, Helmholtz, and Poincare.

Jakob Kunz

The stubborn skepticism with which the imaginative, radical, and half-proved new ideas in physics were received were typified in Professor Jakob Kunz, who received his Ph.D. degree at Zurich in 1902 and came to Illinois in 1909. He was in many ways the intellectual leader of the department. He taught most of the graduate courses and directed more than half of the 36 Ph.D. thesis researches completed prior to 1929

In 1914, after the initial great discoveries of Einstein, Rutherford and Bohr, Kunz published "An Attempt at an Electromagnetic Emission Theory of Light," which he prefaced with the following reference to Einstein's Theory of Relativity:

"When a physical theory which is mathematically complicated and is only an approximation cuts so deeply in our fundamental notions, and renders the phenomena so incomprehensible, the freedom of advancing other theories should be granted. In the following, a theory will be developed which agrees with that of relativity in many features, but gives an entirely different aspect to the world."

Professor Kunz and his students made substantial contributions in experimental physics. He developed the science and art of making sensitive alkali hydride photocells and encouraged their application, notably in stellar photometry with Professor Stebbins of the Astronomy Department and in the photographic recording and reproduction of speech by Professor Tykociner. He was, however, more interested in the basic laws of the photoelectric effect. By 1917, he had made his peace with the quantum interpretation of the effect and reported a series of experiments which verified aspects predicted by the quantum theory. These experiments were done at the Nela Research Laboratory in Cleveland. In his paper he gave thanks to the director and staff for facilities and suggestions and "for the very good time spent in an excellent company of human scientists." Professor Kunz was himself a very human and engaging scientist.

Floyd Rowe Watson

Another member of the faculty in this period who made a special contribution to applied physics was Floyd Watson. I refer to his work in architectural acoustics which he began in 1908 and which he continued long after his retirement to California in 1939*. His interest in acoustics began when the University Auditorium was completed, and the Physics Department was asked what could be done about its atrocious acoustics. You may think that the Auditorium's acoustics are not very good now, but listen to Professor Watson's description of the situation in 1908:

"If an observer stood on the platform and clapped his hands, a veritable chaos of sound resulted. Echoes were heard from every direction and reverberations continued for a number of seconds before all was still again. Speakers found their utterances thrown back at them, and auditors all over the house experienced difficulty in understanding what was said. On one occasion the University band played a piece which featured a xylophone solo with accompaniment by the other instruments. It so happened that the leader heard the echo more strongly than the direct sound and beat time with it. Players near the xylophone kept time to the direct sound, while those farther away followed the echo. The confusion may well be imagined.

"Thus it seemed that the Auditorium was doomed to be an acoustical horror; that speakers and singers would avoid it, and that auditors would attend entertainments in it only under protest. But the apparent misfortune was in one way a benefit since it provided an opportunity to study defective acoustics under exceptionally good conditions and led to conclusions that not only allowed the Auditorium to be improved but also indicated some of the pitfalls to be avoided in future construction of other halls."

In 1908, Professor Watson began a systematic investigation of the acoustical properties of the auditorium and their improvement. He had no previous special

*Professor Watson enjoyed his 100th. birthday on April 23, 1972.

knowledge of the subject. He studied the classical works of Rayleigh and Lamb and the practical investigations by Sabine at Harvard on the determination and control of reverberation time, which is the most important single element in acoustical quality. He had to beat off popular notions of cures, such as the stretching of miles of wire in the room. He devised an ingenious method of tracing the troublesome echoes. A noisy arc lamp was placed at the focus of a parabolic mirror 50 centimeters in diameter. The light beam served as a tracer for the high-frequency hissing sound from the arc which was also moderately well directed by the mirror. By means of suitably placed mirrors on the walls and ceiling of the Auditorium, the paths of the echoing sound could be traced through one to four reflections. The uses of plane and parabolic reflecting boards to control the echoes were investigated. Sabine's methods of determining reverberation times were used and elaborated.

After extensive investigation, Watson's preferred solution was a complete remodeling of the interior of the Auditorium. But the architects wanted to preserve the interior design and, anyway, remodeling was too expensive. So the primary means of solution was the hanging of large curtains of flannel, velour, and canvas at appropriate places. The hangings most effective in reducing echoes were four large and droopy pieces of canvas under the central dome. These were no doubt forerunners of the so-called "clouds" which are sometimes used nowadays as elements in acoustical design.

Professor Watson was not happy with the results, but he did make the Auditorium usable. Under his supervision, modern acoustical materials have long since replaced those which were available in 1910 and have brought the room to its present tolerable state.

Professor Watson became a recognized expert in architectural acoustics. He also continued laboratory research on sound and acoustic materials until his retirement in 1939. A number of students did master's and doctor's thesis research under his direction.

So much for the second and Carman period in the history of the department, 1896 to 1929. It was a stable period of rather slow growth. In 1929 when Professor Carman retired, the permanent faculty consisted of seven members. Of these, four had come to Illinois by 1903, two more by 1909, and only one in the last 20 years of the Carman period. At Illinois and elsewhere hundreds of students were registered in the introductory courses, but few concentrated in advanced physics. The competition among universities for good graduate students was as intense as it is today, though on a much smaller scale. The average number of Ph.D. degrees in physics at Illinois in the early 1920's was two per year. Professor Carman remarked that the national production of Ph.D.'s in 1921-22 was 21. In the middle 1960's, approximately 1000 Ph.D. degrees in physics were awarded annually in the United States, approximately 35 at Illinois. Thus, despite the relatively small scale of operation in the Physics Department in the twenties, Illinois was producing a larger fraction of the total number of Ph.D. physicists than it is today.

THIRD PERIOD IN THE FIRST CENTURY OF THE PHYSICS DEPARTMENT, 1929-1968

Francis Wheeler Loomis

The third period in the life of the department began in 1929 when Wheeler Loomis came to the department as Head. It is a long and eventful period. There are, of course, vast differences between the present department and the department of the early thirties. World War II violently interrupted its development. Nevertheless, the new outlook, values and atmosphere which Loomis established and which still prevail, give the entire period a remarkable continuity and unity.

In this period, Wheeler Loomis was Head of the Department for 28 years; 1929 to 1957; Frederick Seitz for seven years, 1957 to 1964; and G. M. Almy from 1964 to 1970.* P. G. Kruger was Acting Head from 1941 to 1946 and Almy in 1951-52, periods in which Loomis was on leave to administer federal defense laboratories. Almy was Associate Head from 1952 to 1964. George A. Russell was appointed Associate Head in 1968.

Loomis was 40 years of age, Associate Professor of Physics at New York University, and on sabbatical leave in Europe at the time he was offered the position at Illinois. He came to visit, and somewhat to his own surprise, he decided to accept it. He has said that though the department had been rather static for some time, he was attracted by the fact that both Chemistry and Mathematics at Illinois had been built up to rank among the best departments in the country, and by the personal qualities and the evident support of the Dean of Engineering, Milo S. Ketchum.

Wheeler Loomis is very widely known for his talents and accomplishments in science administration, in which he was almost completely absorbed after about 1940. His substantial contributions to physics are less well known to the present generation of physicists. His principal field of research was molecular spectroscopy, in the heyday of the branch of physics. Let me mention three of his contributions. 1) He discovered the isotope effect in molecular spectra in 1920, a year or two after Aston established the existence of isotopes. 2) He analyzed and interpreted the fluorescent spectra of the iodine molecule in a remarkable series of papers between 1926 and 1930. Of special interest was the explanation, in 1928, of alternate missing lines in the optically excited spectrum, an early evidence of the

*Almy retired in 1970 and Ralph O. Simmons was appointed Head of Department.

symmetry principles which were just beginning to emerge from the then very new quantum mechanics. 3) At Illinois he and his students investigated extensively the spectra of the alkali metal diatomic molecules. One ingenious development was the use of magnetic rotation of polarized light to reduce the many-line, overlapping spectrum bands to a single representative line for each band. This simplification of the spectrum enabled them to extend the analysis to high vibrational states of the molecules and greatly to improve the determination of the molecular characteristics.

One of Loomis' students at Illinois was Polykarp Kusch (Ph.D. 1936), who later at Columbia did experiments on the precise measurement of the magnetic moment of the electron for which he was awarded a Nobel Prize in 1955. His thesis research at Illinois was on the molecular spectrum of Cesium. Kusch interpreted much of the spectrum, but some unsolved features rankled in his mind for about thirty years and he finally came back to them. In the summer of 1967 Kusch sent Loomis, as a present on his 78th. birthday, a manuscript entitled "An Analysis of the 6250 Angstrom Band System of Cs_2."

When Loomis came to Illinois he promptly brought in four young instructors: J. H. Bartlett and G. M. Almy in 1930, P. G. Kruger and H. M. Mott-Smith in 1931. Excellent equipment for the study of atomic and molecular spectra was obtained and research in the field was vigorously pursued. Forty Ph.D.'s were graduated in the next decade as compared with 36 in the previous 20 years. This progress was made in spite of the great depression which closed in on the University in 1932 and slowed the progress of the department for five years. The constraints were vividly described by Loomis in his report of the year 1934-35:

"The department, whose operating expenses have been reduced to a starvation point for over three years, suffered a financial crisis this winter and pretty nearly had to close up. It was rescued, temporarily, by the allotment of \$2200 from general and engineering funds ... It is almost impossible to convey an adequate idea of the extent to which our work, both in teaching and research, has been hampered and made inefficient and how all progress has been blocked by the inability to buy necessary articles. We should have had pretty nearly to cease activity in research if it hadn't been for the equipment which was bought in our three boom years, 1929-32..."

Finding jobs for the graduates was not easy. In 1936, two of the Ph.D.'s secured appointments at the National Bureau of Standards by competing in Civil Service examinations which were open to high school graduates. Kusch did well. He got a rare postdoctoral research appointment, with John Tate at Minnesota. The salary, as I recall, was $1000 per year.

In spite of hard times, physics was exciting. 1932 was an especially great year. In the colloquium in 1932, reports on current research included the discoveries of the neutron, the positron, and the deuteron; the first experiments on the disintegration of elements by fast protons (Cockroft-Walton and Lawrence); and on Milne's ideas on the expanding universe.

Nuclear and Particle Physics at Illinois

The depression eased and the department pushed rapidly into nuclear physics along lines that can be traced continuously to many of the present activities in the department.

Loomis' annual report in 1936 describes the building of the first Illinois cyclotron, a two-million-volt machine, as follows:

"The most important new development in the research of the department this year has been the construction of the cyclotron by Professor Kruger, Mr. Green and a group of helpers. Plans for it were laid last spring. Most of the material was ordered during the summer, which Professor Kruger and Mr. Green spent in California, studying and assisting in the similar work of Professor Lawrence. Construction was started in September, and, due to the energy and enthusiasm of Professor Kruger and Mr. Green, the main apparatus is already complete and in operation. That is, a beam has been obtained and brought out of the magnetic field. This has involved the design, construction, and getting into operation of a formidable array of very complicated apparatus, and it is quite a triumph to have succeeded so quickly."

The Mr. Green referred to is George Kenneth Green, Ph.D. Illinois, 1937, who, twenty years later, played a central role in the design, construction, and operation of the 30 billion-volt AGS proton accelerator at the Brookhaven National Laboratory.

Plans for the second cyclotron were begun about 1938 under the leadership of Professor Kruger and the machine was completed in 1943. In the late 1950's it was extensively remodeled and modernized, mainly by Jentschke, Allen, and Yavin. By 1968, 33 Ph.D. thesis researches were completed or in process in the cyclotron laboratory*

John Manley joined the department in 1937 and Leland Haworth in 1938. They built a Cockroft-Walton type of nuclear accelerator. With their students, researches for three Ph.D. theses were completed before Manley and Haworth left for war research in 1941. In 1943, a group of physicists, including Manley, backed a truck to the door of the Physics Laboratory, disassembled and loaded the Cockroft-Walton accelerator into the truck and disappeared into the west. The machine turned up after the war in highly secret Los Alamos.

Maurice Goldhaber came to Illinois in 1938. He had been one of Chadwick's bright young men at Cambridge during the early days of the neutron. At Illinois, he initiated a fruitful program in nuclear physics, using radioactive sources and relatively simple equipment. He and his physicist wife, Gertrude Scharf-Goldhaber, were not allowed to join the war-related research projects because of their foreign origin. Goldhaber, nevertheless, figured out the conditions for sustained neutron-induced nuclear fission and attempted to secure materials to test his ideas and calculations in the basement of the Physics Laboratory. But he found the atom-bomb people completely unresponsive to his request for a little purified uranium.

With his students, Goldhaber did a large part of the basic research that was completed in the department during the war and the immediate post-war years. In the ten years between 1941 and 1951, he directed the research of more than 20 Ph.D. candidates. In 1950, he joined the Brookhaven National Laboratory, where in 1960 he became Head of the Physics Department, and, in 1961, the Director of the Laboratory.

Donald Kerst came to Illinois as an Instructor in 1938, with an intense desire to design and build a magnetic induction accelerator, later named the betatron. With Robert Serber, a young theorist who also joined the faculty in 1938, he worked out the conditions for a magnet that would focus and hold a beam of electrons in a circular orbit for hundreds of thousand of turns. Less than two years later, in July, 1940, the first betatron was in successful operation.

*The cyclotron was closed down and dismantled in 1970.

The first betatron was an elegant little machine. It was an electromagnet in which the current in a single pair of coils induced a changing magnetic field, so distributed as to simultaneously fulfill the three functions of bending the electrons into circular motion, focusing them into a fine beam, and accelerating them to an energy of two million electron volts (MeV). A similar design was used in the second betatron, a 20 MeV machine completed in 1941. In the 300 MeV machine built after the war and completed in 1950, Kerst ingeniously separated magnetically the accelerating and guide fields, thereby accomplishing a great saving in the amount of iron required in the accelerating magnet.

The practical limit on the size or energy of the betatron is the amount of iron required in the accelerating magnet. Kerst readily carried the first two MeV machine in the trunk of his car. The 300 MeV betatron required more than 300 tons of finely laminated iron. For this reason, acceleration by magnetic induction gave way in large circular machines to the use of the synchrotron principle.

The second betatron, 20 MeV in energy, was installed in 1942 in the Abbott Power Plant Building, for want of a better place to put it. The war was on and attention was turned to developing the machine for practical use in x-ray radiography. X-rays are produced when the 20 MeV electrons are made to impinge on a tiny metal target mounted within the doughnut-shaped vacuum chamber in which the electrons are accelerated. The betatron thus became an excellent and unique x-ray machine for detecting flaws in material or mechanisms equivalent in thickness to as much as twelve inches of steel.

For this practical purpose, the Allis-Chalmers Company engineered and built a push-button 25 MeV betatron.

Professor R. K. Hursh in the Ceramic Engineering Department of the University did a superb development of a slip-cast porcelain doughnut-shaped betatron vacuum tube, to which glass arms could be fused for the purpose of leading in wires to the electrodes. The tubes could be permanently sealed off at high vacuum and produced in quantity. This type of tube replaced a continuously pumped tube made of several plates and cylinders of glass, waxed together to form a doughnut shape.

Kerst was drafted to work at Los Alamos in 1943 but the work at Illinois continued with Almy in charge. Kerst requisitioned and diverted to Los Alamos the first of the commercial 25 MeV betatrons, to take stop-action x-ray pictures of explosions. Betatrons were also dilivered to the Rock Island Arsenal in Illinois and the Picatinny Arsenal in New Jersey. Allis-Chalmers continued to manufacture machines for use in radiography and medical therapy.

A good deal of attention was given at Illinois in the late forties to the use of 25 MeV x-rays for medical purposes. The work was led by Dr. Henry Quastler who did some careful experiments on the relative biological effects of 25 MeV x-rays and the much lower energy x-rays and radium gamma rays then in use. Pioneering experiments were also done on the distribution of x-ray dosage in tissue-like material when irradiated by the very penetrating 25 MeV x-rays and electrons. Quastler also attracted young physicists working in the laboratory into research in medical radiology. Several of them later went into important positions at medical centers. Gail Adams went to the University of California in San Francisco and later to the University of Oklahoma. John Laughlin went first to the Illinois Medical Center in Chicago and later became Chief, Division of Physics and Biophysics, Sloan-Kettering Institute and Attending Physicist at Memorial Hospital, New York. Lester Skaggs and Lawrence Lanzl headed up a research program at the University of Chicago and Jaques Ovadia did similar work at the Michael Reese Hospital in Chicago.

In the 1940's, 25 MeV was very high energy and the betatron was credited with a number of firsts. William Koch did the first photofission experiments on the isotopes of uranium and plutonium, during the war and under highly secret conditions. Later on the betatron was used to break open the extensive field photon-induced nuclear processes by Hanson, Kerst, Koch, Becker, Duffield and Almy. The first experiments on high energy electron scattering (at 15 MeV) were done by Hanson, Lyman and their students using an electron beam which was led out of the betatron.

In 1959, Peter Axel made a major improvement in the method of use of the betatron (as a photon-monchromator). With this method the research of Axel, Sutton and students has led to several unique contributions to nuclear processes and structure.

By 1950, when the 300 MeV betatron was completed, it was in competition with a number of machines. Important contributions have been made at Illinois, however, in meson physics, in photodisintegration of nuclei, and in an extensive series of significant experiments on the interactions of photons and the isotopes of hydrogen and helium. The faculty involved included Bernardini, Goldwasser, Hanson, Robinson, J. H. Smith, Koester, Duffield, Sutton and Hummel. Altogether about 65 Ph.D. thesis researches have been completed at the betatron laboratory, almost equally divided between the 25 and 300 MeV machines.*

In the late 1950's, the billion-volt accelerators at the national laboratories moved to the center of the high-energy stage. Several of the faculty who were working with the large betatron, augmented by later additions to the faculty, formed "user groups" who commuted to the Argonne National Laboratory in Argonne, Illinois and other laboratories to do experiments which are then analyzed and computed with facilities at Urbana, Goldwasser, Wattenberg and Sard had major responsibilities in these efforts. This kind of activity will be intensified as the 200 billion-volt accelerator under construction near Batavia, Illinois comes into use. Goldwasser has been involved for years in the national planning that has led to the authorization of the giant accelerator. In July 1967, he accepted the position of Deputy Director of its home, the National Accelerator Laboratory.

An additional major program in nuclear physics is that of Professor Frauenfelder, who first came to Illinois in 1952. His style has been to maintain a flexibility that has enabled him to initiate research on new phenomena and problems quickly and productively. Examples are the Mossbauer effect and a wide range of applications, experiments to test fundamental symmetry principles, and an experimental search for the hypothetical and elusive particle known as the quark.

*Research with the 300 MeV betatron was terminated in 1969. Use of the 25 MeV machine continues. Research is well along on the design and construction of a superconducting linear accelerator which can be used for low energy experiments or as the accelerating element in a microtron design.

The faculty listed below by year of appointment have contributed to experimental research in nuclear and particle physics at Illinois, prior to 1968.

	Years at Illinois	Location on Leaving Illinois
G. M. Almy	1930-1970	Retired (1970)
P. G. Kruger	1931-1970	Retired (1970)
E. B. Jordan	1937-1943	Bennington College
J. H. Manley	1937-1945	Los Alamos Scientific Lab
W. E. Shoupp	1937-1938	Westinghouse Electric Corp.
M. Goldhaber	1938-1950	Brookhaven National Lab
L. J. Haworth	1938-1947	Brookhaven National Lab
D. W. Kerst	1938-1956	General Atomic, California
E. M. Lyman	1938-	
J. R. Richardson	1938-1945	U. C. L. A.
G. D. Adams	1943-1951	Univ. of Cal. Med. Center
G. T. Groetzinger	1943-1945	Ohio State University
L. W. Phillips	1943-1944	University of Buffalo
H. W. Koch	1944-1949	National Bureau of Standards
P. Axel	1949-	
R. A. Becker	1946-1961	Aerospace Corporation, Cal.
R. B. Duffield	1946-1956	General Atomic, Calif.
A. O. Hanson	1946-	
C. S. Robinson	1946-	
C. W. Sherwin	1946-1960	Aerospace Corporation, Cal.
G. F. Tape	1946-1949	Brookhaven National Lab
R. D. Hill	1947-1965	General Research Corp.
J. S. Allen	1948-	
A. Longacre	1948-1957	Syracuse University
R. L. Hulsizer	1949-1965	M.I.T.
W. K. Jentschke	1950-1956	DESY, Hamburg, Germany
G. Ascoli	1950-	
L. Lavatelli	1950-	
G. Bernardini	1951-1959	CERN, Geneva, Switzerland
E. L. Goldwasser	1951-1967	Nat. Accel. Lab. Batavia Ill. (on leave from Ill.)
L. J. Koester, Jr.	1951-	

	Appointment in Physics at Illinois	Destination on Leaving Illinois
J. H. Smith	1951-	
H. Frauenfelder	1952-	
Walter John	1955-1958	Lawrence Rad. Lab (Livermore)
J. P. Hummel	1956-	
A. Wattenberg	1958-	
A. I. Yavin	1958-1960	Univ. of Tel Aviv, Israel
U. E. Kruse	1962-1970 1959-	
M. K. Brussel	1960-	
P. G. Debrunner	1960-	
D. C. Sutton	1960-	
A. Abashian	1961-	
R. D. Sard	1961-	
T. A. O'Halloran	1966-	
D. W. Mortara	1966-	
R. M. Brown	1967-	
B. I. Eisenstein	1967-	
L. E. Holloway	1967-	

Excellent theoretical research in nuclear and particle physics has accompanied and complemented the experimental developments. Most of the theorists came to Illinois early in their careers and rose rapidly in recognition. Many have departed to other leading universities. The faculty on teaching appointment prior to 1970 who have made important contributions to theoretical nuclear and particle research are listed below:

	Years at Illinois	Location on Leaving Ill.
J. H. Bartlett	1930-1965	University of Alabama
R. Serber	1938-1945	Columbia University
S. M. Dancoff	1940-1951	Died August 15, 1951
P. Morrison	1941-1943	Cornell University
H. A. Nye	1941-1946	University of Buffalo
A. T. Nordsieck*	1947-1961	General Motors Res. Lab., Cal.
John Blatt	1949-1953	Univ. of Sidney, Australia
G. F. Chew	1950-1957	Univ. of Calif.- Berkeley
F. E. Low	1952-1957	M.I.T.
A. M. Feingold	1955-1957	University of Utah

	Appointment at Illinois	Position after leaving Illinois
Joseph Weneser	1955-1957	Brookhaven National Lab
J. D. Jackson	1957-1967	University of Calif., Berkeley
D. G. Ravenhall	1957-	
H. W. Wyld	1957-	
K. Nishijima	1959-1967	University of Tokyo
R. Haag	1960-1967	University of Hamburg, Germany
F. T. Adler	1958-	
R. L. Schult	1961-	
J. D. Stack	1966-	
J. D. Sullivan	1967-	
J. A. Wright	1967-	
Lorella M. Jones	1968-	
J. S. Trefil	1968-1970	University of Virginia
S. J. Chang	1969-	

So much for nuclear physics at Illinois from 1935 to about 1968. Let us take up the chronological thread again.

The War Years and Reconstruction

World War II brought a great reduction in the normal activities of the department. About two thirds of the regular faculty including Loomis, the Head of the Department, disappeared into war research and development. The department, however, has an enormous load of teaching military personnel who were in training on the campus. Acting Head P. G. Kruger had to find teachers for a peak load of 2400 students in general physics, a load not approached again until the mid 1960's. Some teachers were recruited from other departments on the campus. After an intensive refresher course, professors of music, architecture, agriculture, and biology, and some faculty wives, did a highly creditable job of teaching physics to regiments of often unwilling soldiers and sailors.

*Arnold Nordsieck contributed to nuclear physics but his profound knowledge ranged over much of physics. He came as close to being a generalist in physics as modern developments will permit. He was cheerfully willing to teach almost any course offered by the department. At the Control Systems Laboratory (1951-1961) his contributions included the early development of complex computer systems for handling radar information, and the electromagnetically supported gyroscope. He resigned in 1961 to accept employment in an industrial laboratory in California. He died, while still active, in 1971.

After the war, the department had to be reconstructed. A number of faculty had resigned their positions at Illinois, but Loomis returned, as did Haworth, Lyman, Kerst, and Dancoff. Sidney Dancoff was a brilliant young theorist who believed strongly that the department had a great future. His presence was a big factor in attracting theorists Arnold Nordsieck, John Blatt, and Geoffrey Chew to join the department. Dancoff's death from cancer in 1951 was a most tragic event in the history of the department.

The faculty was built up steadily after the war, at first in nuclear physics as the above lists show and then in solid state and low temperature physics as will be described later. An unusual addition was made in the case of Willi Jentschke. He was among a group of German and Austrian scientists who were persuaded by the military to come to the United States as a counter move to Soviet inducements. Jentschke was assigned to the Illinois Electrical Engineering Department. He began to slip over to the cyclotron laboratory in the evenings and was soon on the Physics Department staff. He took a leading role in the cyclotron research and development program until 1956. Then he left to go to Hamburg, Germany, where he designed and built a unique, successful, and productive 6 BeV electron accelerator. He became the Director of the associated laboratory, known as DESY (Deutsches Elektronen-Synchrotron). In 1970 he was appointed Director of CERN, at Geneva, Switzerland, the European high-energy accelerator laboratory.

The recovery and rise of science in the universities after the war owed a great deal to the new policy in the federal government to support basic research in the universities. The Office of Naval Research led the way. The first ONR contract with Illinois was written in 1946 and the support was continued until 1968. The scope of research under the initial contract was simply and broadly stated as nuclear physics. The funds have been the principal source of support of the cyclotron and betatron research programs and of very fruitful research in theoretical nuclear and particle physics until 1968. Because of the flexible terms, the department was able to give immediate research support to a variety of programs initiated by such vigorous young physicists as Slichter, Frauenfelder, Wheatley, John Blatt, Chew, and Low as they joined the department. In the first decade of the contract (1946-1956) more than two thirds of the students who received their Ph.D. degrees in physics, 90 out of 128, were supported in research in some way from the funds of the contract.

In the course of time, research support came from other Department of Defense agencies, from the National Science Foundation and, most abundantly, from the Atomic Energy Commission. The "Navy nuclear" contract, however, has a special sigificance in the history of the department, because of its great contribution in the early post-war period to building up and sustaining a strong program of graduate education and basic research.

Another event which had a strong influence on the history of the University and the department was the appointment, in 1947, of Louis J. Ridenour as Dean of the Graduate College and Professor of Physics. In a short and rather stormy four-year period as Dean, Ridenour played a strong role in a number of new developments in the University of which three were of great significance to the Physics Department. These were the founding of the Digital Computer Laboratory and the Control Systems Laboratory (renamed Coordinated Science Laboratory in 1957) and the initiation of solid state physics in the Physics Department.

The development, growth, and transformations of DCL and CSL would make two long and interesting stories. Suffice it to say here that the Physics faculty has been intimately involved in these developments. Professors of Physics, for example, have been involved in the design and construction of the computers called Illiacs I, II, and III. The Directors of CSL from 1951 to 1970 have been Professors of Physics -- F. Seitz, F. W. Loomis, D. Alpert, and W. D. Compton. During the early period of CSL when the war in Korea was on and most of the CSL research was classified for reasons of security, about one third of the Physics faculty was transferred temporarily to CSL. As the emphasis shifted almost entirely to unclassified research, under Alpert and Compton, the scientific interaction of CSL with the Physics Department, as well as with other departments, actually increased. One measure is that five Ph.D. thesis researches in physics have been completed in the CSL laboratory and at least ten were underway in 1968* In the fields of plasma physics under Professors Raether and Bohmer and surface physics under Professors Propst, and Ehrlich, for examples, CSL offers opportunities for graduate research in experimental physics that are not available in the Physics Department itself.

*Through June, 1972, twenty physics Ph.D. theses had been completed in research done at CSL.

Solid State and Low Temperature Physics

Graduate education and research in solid state and low temperature physics began at Illinois in 1949 under the leadership of Frederick Seitz. It had strong initial support from Louis Ridenour in his strategic position as Dean of the Graduate College and has become the broadest and strongest program of its kind in any university.

The seven founders of solid state and low temperature physics at Illinois came to the department between 1949 and 1951. Fred Seitz, the leader of the group, came in 1949 from the Carnegie Institue of Technology. With him came Robert Maurer, and a new Carnegie Ph.D., Dillon Mapother, who initiated experimental low temperature physics at Illinois. In the same year, C. P. Slichter and David Lazarus joined the department as Instructors, with the ink scarcely dry on their Ph.D. diplomas. James Koehler came a year later in 1950. In 1951, John Bardeen was persuaded to come from the Bell Telephone Laboratories to Illinois. These seven men laid the foundation of solid state and low temperature physics at Illinois.

John Wheatley also came to Illinois in the early days of low temperature physics at Illinois, in 1952, as an Instructor, but not initially as an expert in low temperature research. He was attracted by an interest he had in common with Robert Hill, a nuclear physicist in the department, namely the study of the angular correlation of nuclear radiations at low temperatures. Their chief problem initially was that neither of them knew much about low temperature techniques. Wheatley overcame that deficiency handsomely. The study of low temperature methods and phenomena became a passion with him. He ranks at the top in the achievement of low temperature, and he has done fundamental and unique research, particularly in the properties of liquid Helium-3 and of mixtures of Helium-3 and Helium-4. To our great regret, he resigned in 1967 to go to the University of California at San Diego.

John Bardeen, before coming to Illinois, had completed at Bell Labs the research on semiconductors which led to the invention of the trasistor and later to the award of a Nobel Prize to Bardeen, Brattain, and Shockley (1956). At Illinois Bardeen was appointed jointly in Physics and Electrical Engineering. He initiated and developed an excellent and productive semiconductor laboratory, located in the Electrical Engineering Research Laboratory, but interdepartmental in respect to faculty, students, and point of view.

Bardeen also worked away at the theoretical understanding of superconductivity, a phenomenon known since 1911 but for which there was no adequate theory, despite great efforts on the part of many physicists. In 1957, Bardeen, in conjunction with Research Associate Leon Cooper and Ph.D. candidate Robert Schrieffer, announced a theory of superconductivity which has come to be known as the BCS theory. The theory has been highly successful in accounting for many properties of superconductors, and in simulating a great new burst of theoretical and experimental activity in the field at Illinois and elsewhere. It is a profound and significant contribution to physics and was a principal basis for the award of a National Medal of Science to Bardeen in 1966*

Under the leadership of Seitz and Bardeen a strong school has developed in theoretical solid state and low temperature physics, with emphasis on methods for treating large numbers of interacting particles - the many-body problem. The teaching faculty through 1968** in solid state theory has included the following physicists:

	Years at Illinois	Location on Leaving Illinois
F. Seitz	1949-1964	National Academy of Science (President)
J. Bardeen	1951-	
R. M. Thomson	1956-1968	State Univ. of N.Y., Stony Brook
D. Pines	1952-1955 1960-	
J. R. Schrieffer	1959-1962	University of Pennsylvania
L. P. Kadanoff	1961-1969	Brown University
G. A. Baym	1963-	
M. Wortis	1966-	
C. J. Pethick	1966-	
W. E. Massey	1968-1970	Brown University

*The Nobel Prize for Physics in 1972 was awarded to Bardeen, Cooper and Schrieffer in recognition of the success and impact of the BCS theory of Superconductivity.

**Note added in 1973: Solid state theorists who have joined the faculty since 1968 are C. B. Duke (1969), who left to go to the Xerox Corporation in 1972; A. B. Kunz (1969); F. K. Lamb (1970); J. D. Dow (1972); and W. L. McMillan, Ph. D. Illinois '64 (1972). Lamb's interests are mainly in astrophysical applications, which have also become a major research interest of Pines, Baym and Pethick.

Experimental solid state and low temperature research has covered a broad spectrum of fundamental research. Major subjects of interest in solid state physics have included the electronic band structure of metals, semiconductors and insulators, lattice dynamics of crystals, diffusion of atoms and ions in crystals, electronic transport phenomena, the elastic and plastic properties of crystals, the thermal conductivity and specific heat of crystals, the optical properties of solids, magnetic properties, the effect of high-energy particle irradiation on crystals and the behavior of solids under high pressure. In two large specially equipped laboratories for low temperature research the topics of investigation have included the properties of superconductors, normal metals, and liquid helium, and the behavior of materials close to thermodynamic critical points.

There have been 21 experimentalists on the teaching faculty in these fields, of whom 19 were with us in 1968. Each works more or less independently with his group of students, but overlapping interests lead to many strong and fruitful interactions. The distributon of the faculty in the two areas in the order in which they joined the department is as follows:

Solid State		Low Temperature	
R. J. Maurer	1949-	D. E. Mapother	1949-
C. P. Slichter	1949-	J. C. Wheatley	1952-1967
D. Lazarus	1949-	D. M. Ginsberg	1959-
J. S. Koehler	1950-	A. C. Anderson	1961-
F. C. Brown	1953-	C. B. Satterthwaite	1961-
P. Handler	1956-	J. M. Mochel	1966-
R. O. Simmons	1957-		
C. P. Flynn	1960-		
W. D. Compton	1961-1970		
A. V. Granato	1961-		
H. J. Stapleton	1961-		
M. V. Klein	1962-		
J. J. Gilman	1963-1968		
M. B. Salamon	1966-		
W. S. Williams	1967-		

Ph.D. candidates in solid state physics have also done experimental thesis research with professors in other departments, particularly with

H. G. Drickamer, Chemical Engineering, high pressure properties of materials

C. T. Sah, Electrical Engineering, semiconductors

N. Holonyak, Electrical Engineering, semiconductors

F. M. Propst, Coordinated Science Lab, surface properties of metals

G. Ehrlich, Metallurgy and CSL, surface physics and chemistry

R. N. Peacock, Coordinated Science Lab, thin films

Supporting Staff and Services

A modern physics department and laboratory depends greatly on the supporting services of its technical, secretarial and business staff. When Loomis came to Illinois in 1929, services were provided by one secretary, three mechanics and one lecture demonstration assistant. In 1968 the supporting staff consisted of approximately 95 nonacademic and professional staff distributed among the categories of business managers, secretarial - clerical, mechanics, draftsmen, electronics and accelerator technicians, glassblower, cryogenics technicians, storekeepers, lecture room and teaching laboratory assistants, printing equipment operators, computer programmers, nuclear data analysts, and professional engineers and physicists.

Two highly competent women have occupied the position of departmental secretary since 1912, Mrs. Della Mae Rogers McCown from 1912 to 1959 and Mrs. Bess Matteson since 1959. Mrs. Matteson was the secretary for the betatron laboratory from 1951-1959. Secretarial services in 1968 require a total staff of 15. A most important adjunct to these services is the printing shop originally set up by Mrs. Margaret Runkel in 1962 and managed since 1964 by Mrs. Naomi Garman. Both of them have provided excellent editorial service as well as management of the printing operations.

Ralph F. Flora played a leading role in building up many of the supporting services. He came to the betatron laboratory in 1947 soon after the beginning of construction of the laboratory and the 300 MeV betatron. In 1951 he became the Business Manager for the Department and in a period of rapid expansion built up for the whole department a first-rate organization to handle the funtions of purchasing, accounting, stores, printing services, nonacademic and student assistant personnel, contract and grant negotiation, with semi-independent service groups for the betatron laboratory and particle physics operations. In anticipation of the opening of the Materials Research Laboratory in 1965, Flora assembled and trained a business staff, with James Pence as Business Manager, which smoothly took over the business operations of the new laboratory as it became independent of the Physics Department.*

Fred Wise and Frank Witt, who occupy positions designated Physical Science Technical Supervisor, have provided essential expert services to the Department and the Materials Research Laboratory. Wise has been in charge of shop services since 1959. Witt came to the department in 1950. He is an inventive designer of cryogenic and vacuum equipment. His most widely appreciated contribution was the early development of a steady supply of liquid helium, which is required as a refrigerant by solid state and low temperature researchers continuously at the rate of hundreds of liters per day.

The Problem of Space for the Physics Department

The Physics Laboratory at Green and Mathews Streets, completed in 1909, provided ample space for the Department until about 1938. At that time the Department secured a garage on Goodwin Street to house the cyclotron. It was modified and expanded, and named the Nuclear Radiation Laboratory. From 1932 to 1954 a series of alterations in the Physics Laboratory brought marginal space into use as research laboratories and offices until every nook from basement to attic was converted into usable space. The net assignable space grew to a total of about 65,000 square feet.

A State appropriation of $1,500,000 was secured in 1945 to build the 300 MeV betatron and the laboratory in Stadium Drive to house the betatrons. At Kerst's insistence, the building was named the Physics Research Laboratory, rather than Betatron Laboratory; he predicted correctly that the building would outlast the betatrons.

*After Ralph Flora's death, in 1969, James Pence became the Business Manager for the Department.

In the 1950's, with rising enrollments and the development of solid state research, the need for additional space had become really acute. In 1957 an appropriation was obtained to build half of a Physics Building on Green Street, east of Goodwin Street. The entire building was planned in detail and one half was built, its west wall consisting of the exposed concrete blocks which later became the walls of interior rooms. The half-building was occupied in 1959. The second half was built in the 1961-63 biennium. It was occupied in September, 1963 and the old building, the Physics Laboratory, was vacated. The new Physics Building contained approximately 113,000 square feet of usable space and was built at a cost of approximately $4,300,000.

During the seven years between planning and occupation of the Physics Building, 1956 to 1963, the Department and its work had expanded in all respects by more than the increase in usable space provided in the new building. When all came in who had remained in the old Physics Laboratory during the construction of the second half of the new building the Department was about as crowded for space as it ever had been.

The situation was relieved by the building of the Materials Research Laboratory, completed in 1965. It is a research laboratory for solid state sciences and is connected to the Physics Building. About half of its space was allocated to Physics faculty and graduate students in solid state and low temperature physics. Four other departments also were assigned space in M.R.L.

Fred Seitz took the lead in establishing the interdepartmental M.R.L. With great effort, skill and endurance he brought about an arrangement in which the Atomic Energy Commission and the Advanced Research Projects Agency of the Department of Defense, through two contracts, supported both a broad research program and the amortization of most of the cost of the building. In 1963, as Seitz disengaged from active participation in the work of the Physics Department and Materials Research Laboratory, Robert Maurer was appointed Director of M.R.L. and George Russell became the Associate Director.

Numbers of Graduates in Physics in Illinois

The primary function and justification of the Department has always been education. Since the first course in physics was introduced by Stillman Robinson in 1870 good teaching has been stressed. The program in 1968 ranges from introductory physics courses in which approximately 2200 students enroll each semester to Ph.D. thesis research in which approximately 150 students are engaged at any time. A major aim in all of the research which has been undertaken in the department has been to provide Ph.D. candidates with the knowledge which will bring them to the frontiers in their special fields and the experience which will enable them to carry on the advancement of their fields.

The first bachelor's degree in physics was awarded in 1923. Through June, 1968, the total number of baccalaureates was 1012. The rate in the late 1960's is approximately 65 per year. This is somewhat more than one per cent of the national output of bachelor's degrees in physics.

The Ph.D. degree in physics has been awarded to 509 candidates, including the June, 1968 class. The first two Ph.D. degrees were granted in 1910, the 100th. in 1943. In the late 1960's about 40 Ph.D. degrees in physics are awarded per year, which is approximately three per cent of the national output.

A kind of education which has expanded greatly since World War II is postdoctoral education and research. Since 1946 more than 300 young Ph.D.'s mostly from other universities and many from abroad, have held research appointments in the Department for periods of one to three years. The purposes of these appointments are the acceleration of the research program and the further education of young physicists. In each appointment both aims have usually been realized. The postdoctorates have contributed a great deal to the research accomplishments of the Department and have gained confidence in their ability to strike out independently in research. We can add them to the educational output of the Department.

There is one more kind of "graduate" for which a department may take pride and some credit. He is the young faculty member who rises to wide recognition in the environment and conditions provided by the department and then moves on into high position in another university or organization. The lists of faculty which appeared earlier in this story contained a number of examples, particularly among the theoretical physicists. Another impressive group, listed below, consists of former faculty members who, in 1968, hold administrative positions which are national in scope. It is not far from the fact to say that each held his first faculty position at Illinois, with the exception of Seitz, who was appointed Head of Department at the Carnegie Institute of Technology at age 30, seven years before he came to Illinois.

Former Young Faculty Members Now in National Administrative Posts

	Years at Illinois	Position in 1968
R. B. Duffield	1946-1956	Director, Argonne National Lab.
M. Goldhaber	1938-1950	Director, Brookhaven National Lab.
E. L. Goldwasser	1951-1968	Deputy Director National Accelerator Lab.
L. J. Haworth	1938-1947	Director, National Science Foundation
W. Jentschke	1950-1956	Director, DESY, Hamburg, Germany
H. W. Koch	1944-1949	Director, American Inst of Physics
F. Seitz	1949-1965	Pres. Nat. Academy of Sci. President, Rockefeller U.
G. E. Tape	1945-1950	Commissioner, Atomic Energy Commission

So, during the 100th year of the University, the Physics Department graduated its 1000th Bachelor of Science and its 500th Doctor of Philosophy. It also appointed its 300th postdoctoral research associate. Members of the faculty have typically come in as young men and typically have risen to high recognition in their special fields. Some were not here to celebrate the Centennial of the University and of Physics in the University, but they all have contributed to the strength and record of accomplishment of a great Department.

Numbers of Illinois Ph.D. Degrees in Physics Through 1972.

The plot below shows the number of Ph.D. degrees in physics granted per calendar year from 1910 through 1972, and also the cumulative total number of degrees through the same period. The total through October 1972 is 681. The steep rise after World War II is apparent and the leveling off or reduction in the 1970's is beginning to show.