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BERGEN DAVIS

1869—1958

A Biographical Memoir by
HAROLD W. WEBB

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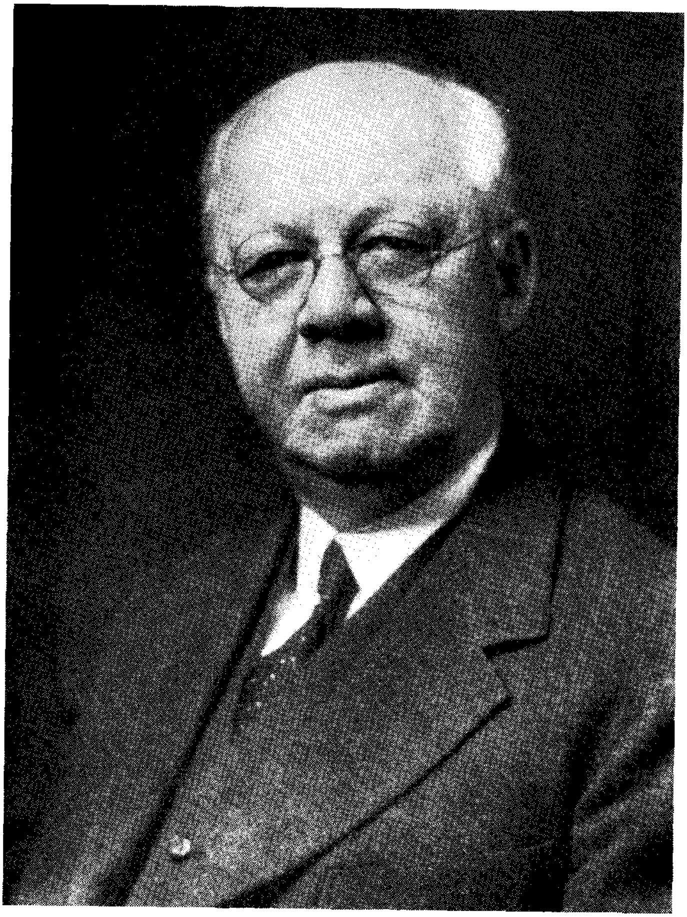

Bergen Davis

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"ALTOGETHER, he is one of those rare men who simply cannot help being a scientific investigator." These words were said of Bergen Davis early in his career by the late Dean George B. Pegram. This characteristic, the unusual will power which enabled him to succeed in spite of a lifelong fight for health, a passionate love of books, and a remarkable memory for what he had read and observed are the keys to understanding Bergen Davis's career and scientific accomplishments.

Bergen Davis was born on March 31, 1869, on a 125-acre farm near Whitehouse, New Jersey, the fourth son of John Davis and Catherine Dilts Davis. His Holland-Dutch ancestors had acquired the farm in the 1730s from the Carteret grant. His father did diversified farming, with corn the chief market product, and produced nearly all the foodstuffs used by the family. Davis was always proud of his knowledge of the processes and methods used in farming.

He was a frail boy and in ill-health, so that he was able to do only the lightest of tasks on the farm. His schooling was limited to attendance at the nearby one-room district school. At the age of fourteen he became ill with tuberculosis, which confined him to the house for four years, making attendance at high school impossible. He was fortunate in that the Hunterdon County library was housed in the nearby school, so that he had access to many books and early developed a fondness for good reading. Throughout his life this love of good literature was an enduring source of satisfaction and pleasure to him. He often said that the great advantage of ill-health was that it gave him time for reading and, what was more important, time to think over what he had read. His special taste was for scientific writings, which interested him from the very first. But he also became very fond of history, poetry, and biography. Macauley's *History of England, The Decline and Fall of the Roman Empire, Paradise Lost,* and Tennyson's poems, as well as most of the standard fiction, were among the books he read as a boy. He spent long hours reading the fifteen-volume American edition of *Chambers's Encyclopaedia,* especially the signed articles with their authentic knowledge of many subjects. With his retentive memory Davis was able throughout his life to draw on the store of information thus acquired.

Becoming interested in physical phenomena at an early age, Davis read and studied every scientific book and magazine he could find. The *Scientific American,* the physics articles in the *Encyclopaedia,* and a book on popular astronomy were among his early readings. At the age of fifteen, while he was confined to the house, he came into possession of a four-volume work on physics through his brother, then a student at Rutgers College. With great delight he read these volumes through, mastering most of the contents and working out most of the problems. Later he became interested in geometrical optics and in order to understand it better taught himself geometry and trigonometry. Like most boys he played with electrical devices such as the telegraph and telephone.

At the age of nineteen Davis had recovered his health sufficiently to begin teaching in the country school near his home. This he did for two years, during which time he prepared himself for college by teaching himself algebra and other required subjects. In 1891 his savings and a small inheritance made it possible for him to enter Rutgers College, where he held a county scholarship. After three years in college he was compelled to interrupt his course and spend a year teaching in the district school in order to earn money to complete his course. This he did in the following year, graduating with the B.S. degree in 1896. His life at Rutgers was very stimulating and enjoyable, and he made many pleasant associations which he kept up in later years. He was a member of the Delta Upsilon Fraternity, the membership of which was based on scholarship. In 1941 he was the delegate from Columbia University to the 175th Anniversary Convocation at Rutgers University.

During the three years following graduation Davis taught a class of teen-age boys at the School for the Deaf then on Lexington Avenue in New York City. He was a popular and successful teacher but found the work very exhausting and uncongenial, as his interests were in science. Fortunately he became acquainted with Professor Ogden N. Rood, head of the Department of Physics at Columbia University, who was impressed with his promise and enthusiasm and gave him permission to work in the University's physics laboratories. Davis took advantage of this and as soon as he was free of his classes at the School he would take a streetcar across town to the University and would spend many hours in the laboratory. His earnestness and his original ideas attracted the attention of Professor Robert S. Woodward, who offered him a fellowship in theoretical physics. Davis did not accept this, as his training in mathematics was insufficient at that time. However, in the following year, 1899, he was awarded a University Fellowship and began his graduate work at Columbia. In June, 1900, he received the degree of Master of Arts and in the following year he held an appointment as Assistant in Physics.

At that time there was little research activity in physics at Columbia. Professor Rood was about to retire and was no longer actively engaged in research. The laboratory facilities were pitifully poor and the departmental budget was small, so that most of the equipment was homemade or improvised. However, Davis's enthusiasm and driving interest plunged him at once into research work. He chose the field of sound, which was at that time a popular subject for investigation, partly because the department had an adequate supply of large organ pipes. Before the year was over Davis submitted for publication a short paper describing measurements of the distribution of velocity and pressure along the standing waves in a sounding organ pipe. As no equipment was available for making these measurements Davis invented the "sound mill," a device constructed of small gelatine medicine capsules. He had discovered that a small cylinder closed at one end, when placed in a sounding organ pipe, tended to set itself at right-angles to the motion of the air and was acted upon by a force impelling it in the direction of the closed end. By mounting the capsules on a torsion fiber he found that this force could be determined and the amplitude of the air vibrations measured. In the following year he published two more papers describing these studies. These were later expanded into a dissertation for the Ph.D. degree, which he received in 1901. While his investigations in later years were in very different fields, Davis always retained his interest in the field of sound and for many years he gave a nonmathematical course on the subject for graduate students. This was noted for its interesting and spectacular demonstrations, among which was his special favorite, a large organ pipe with a glass wall. The students in the neighboring laboratories were always made aware of the fact that Davis had reached that part of the course by the roar coming out of the lecture room.

Davis early realized his need for a broader training in physics, which at that time was available only abroad. After receiving his doctorate he went overseas, where he spent one year in Göttingen and a second year in Cambridge, England. This was made possible by the award to him of the John Tyndall Fellowship, which he held for two years. His work at Göttingen was under Professor E. Reiche, then active in the comparatively new field of discharge through gases. There Davis's first experimental work was the investigation of the motion of ions in a variable magnetic field. Later he began a study of the electrodeless discharge in which he investigated the effect of the frequency of the exciting voltage. This investigation was followed up in later years and resulted in several more papers covering both experiment and theory.

The following year was spent at the Cavendish Laboratory in Cambridge, then the center of the "new physics." There he came under the influence and inspiring guidance of Professor J. J. Thomson in the period when research on gaseous discharges and the properties of the newly discovered electron was at its height. "J. J." was both cordial and helpful and Davis carried on the work on the electrodeless discharge which he had started at Göttingen.

This year at Cambridge had a profound effect on Davis and his future career in research. There was at the Cavendish Laboratory at that period an unusually fine group of scholars, among whom was Ernest Rutherford. Davis found the life there both stimulating and congenial. His association with Thomson, who was then the world's leader in physical research and a man dedicated to his investigations, was a source of inspiration which heightened his already great enthusiasm for pure research. Although Thomson was a good mathematician, he often took the intuitive or pictorial approach to a problem with interesting and productive results. This especially appealed to Davis, whose training and inclination led him to attack a problem from the experimental rather than the theoretical point of view.

In 1903 Davis returned to New York to take a position at Columbia University as Tutor in Physics. He successively held appointments as Instructor from 1907 to 1909, as Adjunct Professor from 1909 to 1913, as Associate Professor from 1913 to 1919, and as Professor of Physics from 1919 until his retirement in 1939 at the age of seventy, when he was appointed Professor Emeritus of Physics. His first few years as a teacher were somewhat routine, but in 1909 he was given the important task of directing the undergraduate physics laboratories and supervising the quiz sections of the large undergraduate lecture courses, a very responsible task requiring considerable judgment and tact. He was very successful in this work. At this time he was also put in charge of the course in physics given for the nonprofessional students in Columbia College.

On his return in 1903 Davis brought back from Cambridge a heightened interest in gaseous discharges and shortly had a group of students working in this field. His laboratory was often referred to by the students as "The Little Cavendish," and was the start of a new era of research at Columbia. In addition to papers by his research students, he published papers dealing with the theory of the electrodeless discharge and with the theory of ionization by negative ions, both following the classical lines of the Townsend theory. At this time he started the graduate course on "Discharge through Gases," which for many years was noted for its interesting and spectacular demonstrations. He also became interested in certain electromagnetic phenomena and in 1907 published an account of his investigation of the results announced by an Italian physicist, who reported the production of an electric current by light incident on a moving conductor. Davis showed that the reported measurements were in error and that no measurable effect existed. In the same year he was awarded the Ernest Kempton Adams Fellowship for a period of two years to enable him to carry out an ambitious but unrewarding experiment on the optical properties of the ether, which at that time was still a favorite subject for investigation. This recognition was a real compliment to the recipient, who was then only an instructor, as this fellowship is usually given to those of established reputation.

In 1912 Davis was forced to give up his work at the University to rest for one year because of a recurrence of the tuberculosis which had laid him up for four years in his teens. During this year he spent much time out-of-doors and took up the game of golf. For many years thereafter he played whenever the opportunity offered. I had the pleasure of playing with him over many of the courses in the East from Williamstown in Massachusetts to Pinehurst in North Carolina. His golf was only average and he spent a fair part of his time in the sand traps, but he made up for his lack of skill by his enthusiasm and the keen enjoyment he derived from the game.

While on leave from the University he busied himself with working out the theory of the "corona" occurring on power transmission lines. The result was published in 1914 and was one of his best contributions, highly regarded by the electrical engineers. At the end of the year he had sufficiently recovered his health to return to active duty but always, thereafter, found it necessary to carefully conserve his strength.

When Davis began to do research in physics the subject was entering a period of transition from the "classical" to the "modern" physics. The start of the century saw not only important advances in physics but also the introduction of new basic ideas and methods. The discovery of X-rays, radioactivity, and the electron had opened up new fields of investigation. The concept of the energy quantum, developed by Planck in 1900 and applied in 1913 by Niels Bohr in his model of the atom, and the Einstein relativity theory opened up vast new fields of experimental investigation and, equally important, resulted in new methods of theoretical treatment. The early training which Davis received at Columbia was in the old tradition, methods, and concepts of the nineteenth century, and most of his teachers were men who, like Planck himself, were never happy with the "new physics." Nevertheless, Davis was among the first to take up research in these new fields.

By 1915 Davis and his students were engaged in experiments in the field of "atomic physics," suggested by Bohr's quantum theory of the atom. One of the early researches, which turned out to be one of his greatest achievements, was a study of ionization and radiation potentials carried out with his assistant, F. S. Goucher. Working with the Bohr atomic model, Franck and Hertz had published in Germany an important paper describing measurements of the ionization in a gas produced by an electron as a function of its energy. Their results were striking but ambiguous, as ionization was apparently occurring at very low energies in disagreement with other observations. By introducing an additional grid into the experimental tube and by manipulating the accelerating voltages applied to the electrons, Davis and Goucher were able to separate out the current in the tube arising from the ionization of the gas and to show that the rest of the current was due to the photoelectric effect on the electrodes of radiation produced by the inelastic impact of electrons on the atoms. The discovery of this new effect explained the earlier observed discrepancies and demonstrated the validity of some of the basic assumptions of the Bohr theory. It was especially significant in that it was an important step in laying the foundation for the far-reaching field of "atomic physics." The experiment initiated a host of investigations carried out in the laboratories throughout the world. However, Davis and his students contributed only a few more papers to this phase of atomic physics, as he had already become interested in the X-ray studies suggested by the Bohr theory. These studies covered most of the rest of his active research life and resulted in some forty papers, of which twenty were published as the doctoral dissertations of his research students. These and the Davis and Goucher researches were his most important scientific contributions.

It may be of interest to mention that Davis's first use of X-rays, outside of the lecture room, was at the beginning of the First World War before the entry of the United States. Cotton, not having been declared contraband, was still being shipped to Germany. However, the British were much concerned in preventing contraband such as copper and rubber from being concealed in the cotton bales. After trying other means of detection without success, they called for help from the Department of Physics at Columbia. Davis with other members of the Department set up an X-ray machine on the pier and arranged for its operation. The author of this memoir, then one of the younger members of the Department, well remembers the winter days spent on a cold river pier in Brooklyn nursing a temperamental X-ray tube as the stevedores trucked bale after bale of cotton in front of the X-ray machine to be examined by the British inspector.

When Davis began to work in the X-ray field there was very little high-quality specialized equipment available, and much of the apparatus which he used for precision measurements was designed and built under his supervision. It was necessary to adapt high-voltage transformers and to construct high-voltage condensers with large sheets of glass coated with tinfoil and immersed in huge tanks of oil. A secondhand 500-cycle generator with a unique set of starting and speed-control devices furnished the power to operate the plant. Instruments for determining the voltage and measuring the feeble currents produced in the X-ray spectrometers were designed, built, and calibrated. As the measurements became more and more exacting, calling for greater and greater precision, more refined and delicate equipment was needed and constructed. The precision spectrometer which was used in some of his finest measurements was designed and built in the department shop with the aid of its precise circular dividing engine. The labor and thought which Davis put into this construction was very great, but it gave him much satisfaction and pleasure when his efforts resulted in one of the best-equipped X-ray research laboratories of the time.

His researches in X-rays covered a broad field of investigation. In 1917 he published two theoretical papers on continuous and characteristic X-ray emission. To check these theoretical results an extended set of measurements with the crystal spectrometer was carried out in the laboratory. These measurements were followed by others on the reflection of X-rays from crystals, which involved an extensive study of the X-ray spectrometer. Other investigators had used a double X-ray spectrometer, in which the radiation was reflected successively from two parallel crystals in order to partially eliminate the continuous radiation, but they had had poor success because of the imperfections of the crystals used. Davis studied the effect of polishing on crystal reflection and tested a number of different crystals. He found that, by carefully splitting a good specimen of calcite and using the unpolished natural cleavage surfaces in such a position that the lack of plainness in one was compensated for by that of the other, he could attain a degree of reflection far greater than had been obtained earlier and inferred from the result that the failure to reach the theoretically predicted reflection was due for the most part to crystal imperfections. He went on to improve the double X-ray spectrometer until it had a resolving power ten times greater than that of the single crystal instrument. This spectrometer was used with refined measuring equipment in a series of unusually precise measurements made later in the laboratory. The theory and limitations of the apparatus were discussed in several technical papers.

Among the more important studies which he carried out with this equipment were those of the fine structures and natural breadths and shapes of the K and L lines. He was able to measure spectral lines with breadths which apparently lay below those predicted by classical theory. Later the fine structures of the K and L absorption limits in a number of metals were measured with this instrument and a study made of the effect of chemical combination on the structures. The laboratory then made a series of measurements on the refraction of X-rays by solids. This is interesting, as theoretically the refraction depends on the number of electrons involved and their position in the atom. The effect is very small and very sensitive and precise equipment was needed. Early studies were made on pyrites and later a more precise measurement was carried out using an aluminum prism with an angle of 166°. The results agreed surprisingly well with theoretical predictions.

When Davis retired from active service in the University he had started work on the development of a source of high-voltage for use in the study of nuclear physics, in particular for the generation of neutrons. He published no results of this work, as he was unable to complete the task.

In 1924, as an expert on X-rays, Davis cooperated in the preparation of the International Critical Tables, compiling the section dealing with crystal gratings. For many years he served as a consultant on X-rays to the staff of the Crocker Laboratory for Cancer Research at Columbia University. In 1937 he was appointed a member of the Consulting Board for Cancer Research. He was a member of the Physics Division of the National Research Council from 1923 to 1926.

He was a member of the Optical Society of America, and a fellow of the American Physical Society and of the American Association for the Advancement of Science. In 1932 he served as Vice-President of Section B of the A.A.A.S., and was made an Emeritus Life Member of the Association in 1949.

In 1929 he was elected to the National Academy of Sciences. In the same year he was awarded a bronze medal and a cash prize by the Research Corporation in recognition of his work with the double X-ray spectrometer. He received honorary degrees of Doctor of Science from Columbia University in 1929 and from Rutgers University in 1930.

In 1938 he underwent a serious operation, followed by a coronary heart attack which permanently disabled him, so that he was unable to continue in active service in the University. He was appointed Emeritus Professor of Physics in 1939.

Davis was a man highly regarded by his contemporaries for his unusual originality of conception and ingenuity in execution. It was always a source of great regret to him that he had not had a more rigorous training in mathematics, but he made up to a great extent for this lack of mathematical techniques by a vivid imagination, a keen analytic mind, and intuitive judgment, and was never at a loss for ideas stimulated by his wide reading. He exhibited great skill in designing apparatus for his researches and was resourceful in finding ways around experimental difficulties. On many a morning he would come into the laboratory with some new approach to a knotty problem over which he had spent many wakeful hours. It was his unflagging concentration on the current problem, coupled with a fertile and ingenious mind and practical insight, that accounted for much of his success in research. He spared no efforts in pursuing a particular research problem and in few cases failed to carry through work once undertaken. He was punctual and impatient of delay. Being himself intensely absorbed in his research, he expected his assistants and graduate students to give the same devoted attention to it and was jealous of other activities, scientific as well as social, which interfered with their research work. He worked closely with his graduate students and supported them to the fullest. Some of them well remember his discerning interest in their welfare, often concealed under a bluff manner, and his good advice, perhaps not appreciated at the time.

Although he was intensely interested in and preoccupied by his research projects, he nevertheless derived great pleasure and satisfaction from his undergraduate duties. He always considered the teaching of Physics A one of his favorite tasks. He taught this course, given for nonprofessional students in Columbia College, for thirty years. It was a lively and popular course, thoroughly enjoyed by professor and students. He was a colorful and effective teacher and did not talk over the students' heads, using simple and homely illustrations to make his points clear. He gave the lectures painstaking care and thought and because of his leaning toward the experimental side of physics devised numerous and ingenious lecture demonstrations. His lectures had a character of their own, for he had no use for stereotyped methods. He could speak readily on his feet and usually paced back and forth behind the lecture table as he talked. One student, when asked what Professor Davis had talked about in a lecture, replied that he thought it was about five miles. He had a quick mind and a keen sense of humor and it was known that some students chose the course not only for the physics content but for the man himself. The undergraduates had many interesting tales of incidents in which Professor Davis was the hero of some intellectual argument. He enjoyed the jokes even if they turned upon himself and often told of a meeting with a former student. "Professor Davis, you don't remember me, but I was in your class some fifteen years ago. I'll never forget one thing you taught; that F equals MA." "Fine! Now what do those letters mean?" "I haven't the slightest idea." With the sincere student Davis was invariably patient but he had no time for the man who wished to "get by" without effort. If he discovered a man who showed some originality and initiative he was more than willing to help him. But he never made the mistake of trying to make every student into a potential physicist.

He had little patience with superficiality and was blunt and outspoken, sometimes lacking in tact. His friends and students found him both generous and stimulating. His colleagues knew him as a man of wide interests outside of physics and as a man of strong convictions. He especially enjoyed the contacts and discussions during the lunch hour at the Faculty Club. His menu never varied; he ordered it with a rubber stamp which read: "Crackers and milk; Apple pie; Glass of milk; Bring it all at once." Few lunches were complete without his bringing out a little notebook and a pencil stub to make some arithmetical computation suggested by the conversation. These were always made in longhand, as he would never use a slide rule. After a leisurely lunch, before returning to the laboratory, he usually went to the game room for a game of chess, which was his favorite form of indoor recreation.

Reading remained a great pleasure to him throughout his life. When reading he would become completely absorbed in his book. I well remember returning one evening to the apartment which several of us shared with him at the time to find the rooms dense with smoke and Davis immersed in a book. He was puffing steadily on his pipe, quite unaware of an equally strong column of smoke rising from a burning cushion in a nearby chair. His preference in reading was for history, biography, and poetry. After his retirement he read very extensively and collected a choice library including many American and English classics and Greek and Roman histories. He enjoyed historical novels and on the several trips made to Europe he and Mrs. Davis spent much time visiting the many spots of historical and literary interest. He was also much interested in geography and travel, and in 1930 he and Mrs. Davis made a six months' trip around the world visiting many of the countries of the Far East. A number of long trips had been planned for the years after his retirement and it was a source of deep disappointment to him that failing health made these impossible. Those who knew him in these later years will always remember the fortitude and grace with which he bore ill-health and the many years of retirement.

He died on June 30, 1958. He is survived by his widow, Matie Clark Davis, to whom he was married in 1922.

I take this occasion to express my acknowledgment and thanks to Professor Lucy J. Hayner for her help in collecting the data used in this memoir and in compiling the bibliography which follows, and to Professor Hermon W. Farwell for his helpful suggestions.

KEY TO ABBREVIATIONS

Amer. Jour. Sci. = American Journal of Science
Ann. d. Physik = Annalen der Physik
Jour. Franklin Inst. = Journal of the Franklin Institute
Phil. Mag. = Philosophical Magazine
Physik. Zeit. = Physikalische Zeitschrift
Phys. Rev. = Physical Review
Proc. Nat. Acad. Sci. = Proceedings of the National Academy of Sciences
Sci. = Science
Trans. Amer. Inst. E. E. = Transactions of the American Institute of Electrical Engineers

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