Charles Kittel

1916–2019

BIOGRAPHICAL *Memoirs*

A Biographical Memoir by
Marvin L. Cohen
and Morrel H. Cohen

NATIONAL ACADEMY OF SCIENCES

CHARLES **KITTEL**

July 18, 1916–May 15, 2019

Elected to the NAS, 1957

By Marvin L. Cohen and Morrel H. Cohen

Charles "Charlie" Kittel, famous for his research and teaching in the field of solid state physics (now commonly known as condensed matter physics), passed away peacefully at his home in Berkeley on May 15, 2019, two months before his 103rd birthday. Beyond his pioneering research, Charlie had a major influence on his field through his textbooks, his award-winning teaching activities, and the outstanding cadre of people who studied under him or were attracted to him as colleagues, postdocs, and many senior visitors. His text *Introduction to Solid State Physics* (*ISSP*), originally published in 1953 and now in its eighth edition, was not only the dominant text for teaching in this field, it was on the bookshelf of researchers in academia and industry throughout the world. By the fifth edition, it had been translated into fifteen languages. His choice of content defined so-called "modern solid state physics" for many years, and the subject matter and basic concepts he focused on are still considered to be the core of the field.

Early Life, Education, and Muriel

Charlie was born in New York City on July 18, 1916. His father, George Paul Kittel (1887-1971), a Protestant, was born in Germany and emigrated to San Francisco around 1906. His mother, Helen Lemier Kittel, was born in New York City around 1891. Her parents were Dutch/Austrian Jewish. Charlie had one sibling, a brother, Robert Martine Kittel (1922-1987).

Charlie graduated from the Horace Mann School for Boys in Riverdale, New York, in June 1934. He wrote,

> *It was an incredibly good school, with faculty, headmaster, and students playing equal parts. Most of the students came from creative intellectual, European, and Jewish families in NYC. Many of the students perhaps would not have easily been accepted, for religious reasons, at the classiest Eastern prep schools. Perhaps they did not want to go to such schools.*[1]

In 1934, Charlie entered the Massachusetts Institute of Technology (MIT) as a chemistry major and then became a physics major. In an early demonstration of his clarity of purpose, he took the MIT courses of most interest to him in two years and transferred to Cambridge University in the United Kingdom in 1936, receiving his bachelor of arts two years later. Charlie's classes at Cambridge were at the old Cavendish Laboratory on Free School Lane. The Cavendish was then at its peak as the world center of physics, and Charlie spoke highly about the quality of the lectures and tutorials he attended. He said, "If there is such a thing as learning to think about physics as distinct from learning physics, this is where and when it was done best." The focus on simplicity and clarity in all of his work derived from that time at Cambridge, as did his interest in both solid state and nuclear physics.

He married Muriel A. Lister in England in 1938. Muriel was at Cambridge in Girton College and received bachelor's and master's degrees in English literature. Girton, now coeducational, was Cambridge's first women's college. Muriel later obtained a master's degree from the University of California, Berkeley (UCB) in comparative literature in 1964. She had a prolific and distinguished career as a scholarly translator. She translated numerous poems and prose works in seven languages: ancient Greek, Latin, Provençal, Italian, French, Spanish, and German. Muriel was associated with the UCB Department of Italian (currently Italian Studies), where she translated lectures and articles for regular and visiting faculty. She died in 2009 at age 93.

Charlie's graduate work in theoretical nuclear physics under Gregory Breit at the University of Wisconsin–Madison started in September 1938 and was essentially completed by November 1940, when Breit took him and other students to Washington to participate in the war effort. He received his Ph.D. in June 1941.[2]

Wartime Experiences

During 1940-42 he worked on degaussing ships and on magnetic mine warfare, initially as a research physicist at the Naval Ordnance Laboratory in Washington, then as head of the U.S. Navy's degaussing mission with the British Admiralty in Scotland, and finally in the office of the Navy's attaché in the American Embassy in London. From late 1942 to September 1945, he worked on applying the methods of operations research to antisubmarine warfare in London and Washington, from 1943 on as head at the Navy's Submarine Operations Research Group.[3] The degaussing work was his entrée into applied research on magnetism and was foundational to his post-war pioneering research in magnetism. His later continuing interest, in close collaboration with experimentalists, was foreshadowed then by his desire to see reality for himself: "When was there a worse degaussing design than the original design for the USS New Jersey? I crawled through the hull in the shipyard to see it for myself." *ISSP* was conceived in this period: "I spent occasional lonely evenings in London in 1945 thinking that I would one day write a unifying textbook at the level of the Cambridge lectures."

MIT

At the end of the war, Charlie decided to leave nuclear physics for solid state physics, expecting that those who participated in the Manhattan project would be advantaged in nuclear physics. He returned to MIT in 1945, taking a research associate position in the Research Laboratory of Electronics, where he was assigned to work on raising the upper limit of ultrasonic generation from 15 MHz to 10 GHz, that is, into the microwave range. He had two particularly notable accomplishments at MIT. He showed in 1946 that technologically important fine-particle ferromagnetic materials, e.g., alnico, had high coercivity because the particles were fine enough to remain single domain. The significance of that paper[4] for the magnetic tape recording industry was quickly realized. Also in 1946, James Griffiths found the ferromagnetic resonance frequency in thin films to be proportional to the square root of the product of magnetic induction B and the external field strength H instead of to H alone, as is the case in nuclear and paramagnetic resonance. Three months after Griffiths' paper appeared, Charlie published his proof that the dependence arose from the demagnetizing field,[5] an insight derived from his wartime work on demagnetizing ships. That research and his later work strengthened our theoretical understanding of ferro- and ferrimagnetism, helping to develop it into a mature part of physics.

Bell Labs

The fine-particle and ferromagnetic resonance papers were noticed by William Shockley, who invited Charlie to join a solid state physics group he was building up at Bell Telephone Laboratories in Murray Hill, New Jersey. Charlie was a research physicist in that group from 1947 to 1951, working in theoretical physics with a focus on magnetism, ultrasonics, and the thermal properties of solids. He began by joining the subgroup on ferromagnetics with R. M. Bozorth, E. R. Williams, W. A. Yager and later J. Galt and P. W. Anderson. His primary focus was on magnetism and magnetic resonance. His definitive review of the theory of ferromagnetic domains[6] was written "as a supplement to the Becker and Doering book."[7] The theory of ferrimagnetic resonance followed from his theory of the ferrites.[8] There had long been doubts raised about the validity of spin-wave theory because of the implied flipping of the same spin twice in the presence of two spin waves, impossible for spin ½, but his paper with Herring[9] provided clarity and definitive support. Spin-orbit coupling first emerged as a continuing theme in his work in his explanation of the difference between the gyromagnetic ratio and the spectroscopic splitting factor in ferromagnets.[10] His paper on antiferroelectricity paralleled current theories of ferro-, antiferro-, and ferrimagnetism and included a throwaway footnote inventing ferrielectricity.[11] In a departure from magnetism, he showed that glasses had low thermal conductivity because their structural disorder reduced the phonon mean free path to the atomic scale, a very early recognition of the importance of strong disorder for transport.[12]

Berkeley

Charlie's association with the Physics Department at Berkeley began in 1950 as a visiting Associate Professor. He joined the faculty as Professor of Physics the next year and was granted emeritus in 1978. While it was Charles Townes who told Charlie in 1950 that Berkeley might have a position for him because the department was diversifying its research areas, ironically, Charlie was instrumental in negotiating the hiring of Charlie Townes at Berkeley in 1967.

Charlie felt that he had made the right choice in coming to Berkeley and later wrote,

> *Everything at Berkeley seemed better than at Bell Labs. The salary was better. There were grad students, good ones, and hungry. With U.C. funds and contracts my signature was good for 10K; at Bell when times were good I could sign for $10, as a subgroup head. My colleagues in the Department were generally very intelligent, social, and of high professional standing. There was no one at Bell in experimental solid state physics in the same class as Art Kip.*

Charlie interacted well with the experimental group at Berkeley. In addition to Kip, Mike Tinkham, Alan Portis, Walter Knight, Erwin Hahn, and Carson Jeffries were either his collaborators or the recipients of his suggestions for experimental projects.

After arriving at Berkeley in 1950, Charlie presented a weekly two-hour seminar that was the first exposure to solid state physics for many. The notes became the genesis of the first edition of *ISSP*.

The Levering Act, a law enacted by the state of California in 1950, required state employees to subscribe to a loyalty oath that specifically disavowed radical beliefs. It was aimed in particular at employees of the University of California and had a profound effect on the careers of some graduate students in Berkeley's Physics Department. My (MHC) experience was representative. The oath had been imposed on the Berkeley faculty in the summer of 1950 while I was away, and some faculty left in response, among them theorists in the Physics Department.[13] Unaware of this, I met a fellow physics graduate student, Elihu Abrahams, on my return to campus, ready to start my thesis research in particle theory. Elihu, also intending to become a theorist, informed me despairingly "There's no one to work for."[14] I rushed to my advisor, Francis Jenkins, who told me that he had responsibility for rebuilding the faculty. He warmly recommended that I see Charlie. I did and so did five other students, quickly forming Charlie's first group of graduate students without his need to recruit them. We were Albert Overhauser, Frederic Keffer, Elihu Abrahams, myself (Morrel Cohen), Harvey Kaplan, Jack Tessman, and Yako Yafet and quickly cohered into a group. Charlie gave us each a thesis problem in a different area of modern solid state physics, and each project was designed to be completed in two years or less. By the 1951/52 academic year's end, he'd placed each of us in a position suited to our particular abilities and needs. After listing three possible positions and rejecting each in turn as unsuitable, he said to me "We'll send you to the University of Chicago. With Zener gone, you'll have a clear shot at a professorship." He did send me, and I did become a professor. However, my gratitude to Charlie extends beyond my thesis research and that placement. He taught us by example to search out the essential simplicity in complex physical situations and to explore it with the simplest appropriate tools, an ability evident in his research publications and in his texts. Observing how he had built up a portfolio of suitable problems and assigned them to his students, I learned that a thesis problem should not be just a route to a Ph.D. but an opening to a career in research for the student as well. Observing how he built up solid state physics at Berkeley, I learned how I might build up condensed matter physics at Chicago. He was an inspiring guide.

His ability to attract top students and provide them with projects resulted in first-class research and the development of a strong theory group that went on to have a great positive influence worldwide. He also had an exceptional group of postdoctoral researchers. In his words, "Much of the strength of the theoretical solid state group here came from the great postdocs: Yosida, Elliott, de Gennes, Phillips, Heine, Marshall, and others. They often took grad students under their wing and filled in the huge gaps in my competence and interests." [Kei Yosida, Roger Elliott, Pierre de Gennes, James C. Phillips, Volker Heine, Walter Marshall, and John Hubbard (not mentioned in the quote)]. To illustrate, his student Leonard Kleinman worked with Phillips to introduce pseudopotential theory, which transformed electronic structure computations in condensed matter.[15] He fostered and maintained an outstanding theoretical school composed of talented faculty in addition to his exceptional postdoctoral researchers and graduate students. He hired John Hopfield to the faculty, and when Hopfield left, he hired Marvin Cohen, who in turn hired Leo Falicov and later Steven Louie. He attracted distinguished theorists as visitors like Quin Luttinger and Freeman Dyson, with whom he collaborated. Freeman visited for two summers, and one result was a definitive analysis of spin wave interactions.[16] Luttinger, with Karplus, showed that spin-orbit coupling was responsible for the anomalous hall effect in ferromagnets.[17] Charlie's work with Mal Ruderman and Edward Teller (whose name did not appear on the paper) resulted in the discovery of the RKKY interaction.[18] Many members of his group became world leaders in the field of condensed matter physics, including a Nobel laureate, the late Pierre-Gilles de Gennes.

For much of his career, Charlie focused his research on topics related to understanding the properties of materials. These included semiconductors, magnetic behavior, ferroelectrics, optical properties, electron-spin and nuclear magnetic resonance, and superconductivity. He worked closely with experimentalists who conducted groundbreaking research in semiconductors, magnetism, and nuclear magnetic resonance. Theorists associated with him worked closely with experimentalists, offering physical insights and suggestions for experiments in addition to mathematical approaches for solving physical problems. With Arthur Kip, Paul Levy, and Alan Portis, Charlie carried out one of the earliest studies of electron-spin resonance in color centers.[19] Such centers are now of interest for quantum computing. In a classic paper on cyclotron resonance in p-type germanium, Charlie, Gene Dresselhaus, and Arthur Kip[20] reported the first direct measurement of the kinematics of electrons in solids. They confirmed in quantitative detail the correctness of band theory and demonstrated the importance of including spin-orbit coupling. In many ways, this experiment and theoretical interpretation formed a basis for the quasiparticle concept associated with electronic properties. Charlie received the 1957 Oliver E. Buckley Prize of the American Physical Society for this work. Charlie's emphasis on spin-orbit coupling in this and other work and in his advice to others was prescient in view of the present emphasis on topological matter and spin-orbit engineering. His collaboration with Carson Jeffries on electron-hole drops produced seminal papers on this important subject in the mid-1970s, including observation of the smallest scale manifestation of Alfven waves in nature.[21]

Beyond his work on the properties of materials, Charlie spent several years working on problems in molecular biology, and his paper with Jean-Pierre Changeux generated significant interest in membrane phenomena.[22]

Charlie participated in the activities of the Physics Department, and he and Muriel hosted many social events for the faculty, visitors, postdocs, and students. They raised three children in Berkeley: Peter, Ruth, and Timothy. More generally Charlie is credited with building the solid state (now condensed matter) physics component of Berkeley's Physics Department. In addition to his research contributions, he played a central role in hiring new faculty.

Along with his research and publishing at the cutting edge of condensed matter physics, Charlie established and developed undergraduate and graduate courses in condensed matter physics, thermal physics, and the introductory physics program. His texts in the above areas are classics. He was an award-winning teacher, earning UCB's Distinguished Teaching Award in 1970 and the Oersted Medal from the American Association of Physics Teachers in 1978. As discussed before, his text *Introduction to Solid State Physics* had an enormous influence on the field. When asked about the writing of the book, he said,

> *It grew, but limited to topics that could be treated at an introductory level—I consciously followed the principles of selection (as I imagined them) of the great German textbooks by Jost, Becker, and the appendices to Born, Atomic Physics. Simple models; concrete calculations carried out in detail; little written in words that you could not imagine yourself saying in front of a class.*

Berkeley and Mendocino

Charlie recruited me (MLC) from Bell Labs in 1964 after I had completed only half of my two-year postdoc, as he wanted me to start teaching that fall. He was generous, treated me as an equal from the beginning, and offered mentoring with a light touch. He made me a co-principal investigator on his NSF grant, which I believe is the longest continually running NSF grant and is still operative. We were colleagues and friends throughout the years. In what follows, I will share recollections of Charlie and Berkeley during that period.

In 1964, the Physics Department added Birge Hall to its other two buildings, and Charlie was heavily involved with setting up the theoretical solid state physics group on its fifth floor. He had several students and postdocs and an assistant, Madeline Moore. In those days, many secretaries and assistants typed papers, handled administrative duties, and served almost as personal secretaries. Charlie always controlled his environment, and Madeline helped. To cite an example, there was considerable noise in an area near the classroom where Charlie taught because of construction. Charlie asked Madeline to take care of it, and from then on and for the rest of the semester, on Tuesdays and Thursdays from 9:30 to 11:00 AM, all noisy equipment was shut off. No Chairs or Deans were involved.

The fifth floor of Birge was an active and interactive environment. In addition to the theory graduate students and postdocs, there were visiting theorists and experimental faculty with their groups coming by with their data. Charlie was an early riser, getting to campus before the busy day started and leaving shortly before or after lunch unless there was a seminar he wanted to attend. Madeline handled his schedule, and visitors saw him for short periods. A short period with Charlie was all one usually needed because he quickly got to the point and illustrated what he wanted to say with short relevant calculations, and his physical insight usually did most of the solving of the problem at hand. One had a similar experience when asking him about departmental issues or anything else. There was an economy of words that is evident in his textbooks. One finds a lot of important information in each sentence in his texts. Once, he gently pointed out that a preprint I sent him was too verbose. I agreed and asked for a suggestion. He told me to reread the classic papers of Paul Dirac. I did, and it helped.

During the 1960s, Charlie's group continued to focus on problems in magnetism and statistical physics, but for a while his interests turned to biology, which resulted in some important research with Jean-Pierre Changeux on biological membranes.[22] He worked simultaneously in both fields until the 1970s, when he returned to condensed matter physics and focused heavily on the physics of electron-hole drops in germanium. Carson Jeffries's group was doing experiments at the cutting edge of this field, and Charlie was supplying ideas for experiments and explanations.[21]

Throughout this period, Charlie spent a great deal of time and effort in updating *Introduction to Solid State Physics*. He rewrote parts of the second edition and added new material. The major changes, however, were made in the third and fifth editions. He asked me to read his manuscripts, and his responses were surprising. Most scientists I had known believed that once they wrote something it was sacred. But Charlie was different. If I mentioned that a paragraph or sentence might need more clarity, Charlie rewrote large sections to accommodate my concern. He was also always on the lookout for new material, and he would leave me notes asking about new things he had heard about and whether they were worthy of including in his next edition.

Charlie's mode of communication was often through notes written on a small blue pad with a printed heading "BERKELEY: DEPARTMENT OF PHYSICS." I got hundreds of these over the years with very short messages, sometimes an equation or two, and sometimes a drawing or graph. Often, the questions were about new areas of condensed matter physics like superconducting oxides and buckyballs. Charlie wanted to know the latest, and he wanted to know it as soon as possible. He worked quickly, and it seemed that he was always caught up on his work. From what I saw, he never procrastinated, and projects with deadlines were done ahead of schedule. Never was there a last-minute rush. This meant that a blue note needed instant attention, but in the end I didn't mind because he was always so appreciative, and I always learned something from these exchanges.

Keeping up on medical advances was also an interest for him. He seemed healthy to me, and he did live to a ripe old age, but he was often concerned about his health, and he would ask my advice. In turn, I would consult my friends who were doctors.

In addition to keeping the *ISSP* text current, Charlie spent much time and effort on a text covering our undergraduate thermodynamics and statistical mechanics course. He wrote,

> *The Thermal Physics text, especially the 2nd edition with Herb Kroemer, is a more revolutionary and creative text (the best I've written), and this has drawn much feedback and many nice notes. Kroemer sent in about 200 pages of feedback on the 1st edition, and that is how he found himself as co-author of the 2nd edition.*

In 1969, Charlie decided that he wanted to explore rural living and winemaking. As a result, he and Muriel bought 80 acres of undeveloped land (later extended to 100 acres) in the Anderson Valley in Mendocino County, California, near the town of Philo. Shortly thereafter, they built a cabin that Charlie designed and, with help, constructed. The cabin was off the grid, powered by solar panels and a diesel generator. As was Charlie's style, he said he wanted to control his environment, and he usually did. They planted a vineyard, an acre of mostly Pinot Noir with some Cabernet Sauvignon, and made their own wine. At the beginning the wine was not up to Charlie's standards, but eventually he had some very good years—particularly with the Pinot Noir in my opinion.

Having the cabin changed Charlie's life. At the beginning, he split his time between Berkeley and Philo and kept a regular schedule. This meant that communication via blue notes greatly increased. Since he was away, it was even harder for him to keep up with physics without help. When he retired from the university in 1978, he spent much more time away from Berkeley.

Charlie's version of rural life involved a lot of gardening and tending to the vineyard, but he also read a great deal and relaxed. One story that is similar to his quieting noise on campus during his lectures involved the BBC. As Charlie told it, he liked to listen to the BBC news each afternoon after his nap. When the BBC transmission to his area stopped, he wrote to *The Times* of London. As I remember, his letter was published and was answered by someone who could do something about his problem. After that, Charlie continued to have the BBC news after his nap.

After Muriel's death, Charlie spent more time in Berkeley. Eventually he sold his vineyard and cabin and returned to his house in Berkeley. His health had deteriorated, and eventually he needed 24/7 care that was provided by two excellent caregivers. The doctors would put him in and out of hospice care, which seemed to amuse him. I remember two visits I made to see him. I had heard that he was in hospice and went to his house, but before I went into his room, his caregiver warned me that he would be unlikely to know who I was. When I walked in, Charlie looked up and said, "Hi Marv, how are you, what's happening on the outside?" I answered, "Well Charlie, we have a new Pope, a new UC President, a new Chancellor, a new Dean, and a new Physics Chair." He quickly answered, "Are any of them any good?" This was typical of my conversations with Charlie over the years, and I left happy to have seen him. When I saw him on his 100th birthday, he was much less communicative, but he seemed aware of what I was saying as he happily ate and watched TV.

Charlie's reputation as a leading theorist was international, and he lectured worldwide on his research accomplishments. His honors include being a Fellow of the American Physical Society, the Miller Professor at Berkeley, a Fellow of the American Academy of Arts and Sciences, and a Member of the National Academy of Sciences (USA), elected in 1957.

Charlie will be remembered by his colleagues and the students and postdoctoral researchers whom he mentored as well as the many whose lives he touched. Charlie is survived by his children, Peter, Ruth, and Timothy. We thank Tim for his help with this memoir.

NOTES

1. C. Kittel, autobiographical notes including responses to questions by Spencer Weart, August 26, 1981. Private communication to M. L. Cohen, National Academy of Sciences Archives; and Charles Kittel autobiographical notes, 1982, Niels Bohr Library and Archives, call number MB 2014-1576; 300. All material in this memoir set within quotation marks comes from these sources unless otherwise obvious or noted.

2 He became aware of the importance of spin-orbit coupling in nuclei during his thesis research, leading naturally to his later pioneering recognition of its importance in solids.

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4. Kittel, C. 1946. Theory of the structure of ferromagnetic domains in films and small particles. *Phys. Rev.* 70:965-971.

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