Book Report
Thirty Years That Shook Physics
By George Gamow

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Concepts of Modern Physics
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George Gamow, author of Thirty Years That Shook Physics, was privileged to know many of the founding fathers of modern physics and worked closely with many of them. His personal experience allowed him to write a powerful account of the history and birth of quantum physics. Surrounded by inspirational and seemingly radical research ideas in physics, Gamow made his own contributions by explaining the disintegration of a nucleus as it is collided with alpha particles and the decay of radioactive nuclei through wave mechanics.

In his book, Gamow writes primarily in the third person but occasionally switches to first person to recount a few memories of his own ranging from his own studies and contributions to physics at Göttingen to his recollection of meeting Bohr and de Broglie for the first time. Before many of the physicists discussed this in book made their historic discoveries, scientists such as Newton, Maxwell, Gibbs, and Boltzmann, worked in the fields of physics that pertained to measurable quantities and materials of their time. Gamow focused on the history of quantum theory as the modern branch of physics. Today we tend refer to the areas of physics before quantum theory and relativity as classical physics.

Thermodynamics, an area of study in physics especially concerned with heat, heat transfer, and its ability to do work, makes heavy use of statistical mechanics or the examination of the averages of the properties of large groups of particles. These concepts gave us Maxwell's graphical distribution curves which plotted approximate gas particle velocities at different temperatures. These plots interested two men in the latter part of the nineteenth century who attempted to extend Maxwell's idea to the thermal radiation of heated objects. As the temperature of an object was increased it was known to emit electromagnetic radiation of increasing frequency. When they applied the same distribution curves against high temperature objects, the model quickly began to break down. Mathematically, the model predicted that high temperature bodies should emit dangerously high frequency radiation well into the ultraviolet and shorter wavelengths with no end it sight.

To answer this problem a man named Max Planck, at the turn of the last century, presented a new idea at a meeting of the German Physical Society. At this meeting, Planck suggested that the problem of run-away radiation could be solved if one thought of the energy in electromagnetic waves in the form of distinct packets of energy. Thus was born to the field of physics the idea of quantized energy, eventually providing an explanation for the problem of catastrophic radiation.

Today, the energy quantum is a widely accepted and utilized concept. Planck's radical idea in its time has fueled new discoveries in theoretical physics and provided a foundation for many other fields of study, such as chemistry, to build upon. Planck's energy quanta also had great influence on our understanding of atomic structure. The structure of an atom had been unclear, and a source of varying points of view throughout history, only to be complicated by the experiments of J. J. Thomson that proved it possible to remove small, negatively charged particles from atoms leaving a positively charged substance.

Thomson developed his own model of an atom in which he believed it to be composed mostly of a positively charged material that contains smaller, negatively charged electrons in its interior. These electrons could be excited by the passing of a free electron or after colliding with another electron within the atom. This excitation, he believed, caused the electrons to vibrate emitting light of characteristic frequency. His atomic model grew into acceptance in the scientific community while he and his students attempted to complete it by calculating and explaining line spectra of multiple chemical elements. Their efforts were met with little success.

By this time a young student named Niels Bohr, who had just finished his Ph.D. in Copenhagen, had taken great interest in Thomson's work and joined him in his research at Cambridge. However, Bohr soon believed that Thomson's model needed to be changed. While his concept of light emitted by the electrons seemed to be sound, Bohr argued that he was not considering light as discrete packets of energy. Eventually, Bohr left Cambridge to work with man named Ernest Rutherford who was shooting high-energy alpha-particles at atoms and recording the scattering patterns. This lead Rutherford to create his own model which included a positively charged center that was orbited by ultra-light, negatively charged particles or electrons. Bohr seemed inspired by this new model and continued to investigate his theory that if the electromagnetic energy was quantized, the mechanical energy of the atom should be quantized in the form of distinct energy levels. This new, quantized model suggested by Bohr, seemed to explain with greater accuracy the spectral lines emitted by the hydrogen atom, the simplest of the elements.

Bohr's quantized energy levels or orbits could experimentally show that an electron could shift specific energy levels and emit a single photon of given wavelength or absorb a specific amount of energy. This worked quite well for the simple hydrogen atom. However, as he applied his work to larger elements with additional electrons, it became clear that there was something more governing the energy levels of an atom's electrons.

Wolfgang Pauli realized that the energy levels worked better if each level had an electron quota. This concept of electron quotas forms the basis of the Pauli Principle. This lead to the idea of electron "spin." Two electrons could now co-exist in the one quantum level as long as they possessed opposite angular momentum or spin. By putting a quota on the number of electrons that could co-exist in the same energy level, the mathematical predictions began to accurately predict the experimental results.

During World War I, a French Army radio-communication specialist named Louis de Broglie took an interest in Bohr's electron orbits. Drawing upon his fascination with chamber music, de Broglie imagined the atom as a musical instrument with the ability to emit a basic tone with a series of overtones or harmonics. This lead to his idea of pilot waves or what we call de Broglie waves today. While de Broglie pilot waves were closely modeled after string instruments, his theory lacked a mathematical description of the phenomenon. A generalized mathematical solution which proved de Broglie's idea of pilot waves to be a valid concept was published by Erwin Schrödinger about a year after de Broglie's publication. This pushed de Broglie and his pilot waves along with their associated equation introduced Schrödinger, into their place in the history of quantum theory.

While these great advances were taking place in quantum physics, Einstein's Relativity was taking shape and gaining respect in the community. However as they both grew, there became a need to unite the two seemingly separate advances by uncovering their underlying mathematical commonalities. Utilizing concepts from Pauli's electron spin and de Broglie's wave-like electron, English physicist Paul Dirac was able to come up with a relativistic equation of motion for the wave function of the electron. By adjusting differentials in the newly developed four-dimensional (x,y,z,ict, where ict is effectively the time t with ic to keep physical units correct and c is the velocity of light) Minkowski space of physics, Dirac was able to express the four dimensions in linear terms. This combination of H. Minkowski space which was often used in Einstein's relativity, and a linear relationship effectively united the quantum and relativity theories in modern physics.

Throughout his book, Gamow writes the history of quantum physics divided into eight chapters, each chapter focusing on a particular individual and their most influential contributions to quantum theory. In the final chapter, entitled, "Men At Work," Gamow comments that the chapters of the book have grown shorter, not simply because he is tired of writing the book but that the science is incomplete. Dirac's unification of Relativity and Quantum Theory was the most recent, complete edition to quantum theory. Work on quantum theory continues to become increasingly difficult forcing the pace of great discoveries to slow. Peter Woit comments on this slowing in his book Not Even Wrong. Published forty years later, Not Even Wrong includes a similar but less personal recount of the beginning of quantum physics as well as an analysis of the stalemate that the field seems to be in today. Woit examines a few of the tools in the field and advances in technology that has allowed for greater detail and accuracy in extremely small particles that can be identified after an atom or smaller particle is split using a beam from extremely high energy accelerators such as the 1.96TeV (tera electron volts, 10^{12} eV) Tevatron accelerator at Fermilab on the outskirts of Chicago in the United States. Advances in accelerator and particle tracking and detection technology will contribute to new theories and possibly help prove or disprove existing hypotheses that cannot be confirmed with the technology at our disposal today.

These two authors published books exactly forty years apart and have much of the same confirmed information which represents the slowing of new discoveries in the field of quantum physics. Both Gamow and Woit agree that it is an incomplete science and in order to complete it or even take a step towards completing it, radical new ideas will be required just as the ideas of energy quanta, electron orbits, and electron pilot waves may have seemed outrageous in when originally introduced.

References

Gamow, George. Thirty Years That Shook Physics: The Story Of Quantum Theory. New York: Dover, 1985.

Woit, Peter. Not Even Wrong: The Failure of String Theory and the Search for Unity in Physical Law. New York: Basic Books, 2006.

Appendix

Max Planck
Quantized light/energy into discrete packets solving the run-away radiation problem of statistical mechanics.

Niels Bohr
Quantized the mechanical orbits of electrons in Ruthorford's newly formed atomic model, explaining the characteristic photon emission that results from an electron dropping energy levels.

W. Pauli
Exclusion principle which says that only two electrons can occupy any quantum state. Eventually summarized by Mendeleev in his periodic table. Concept of electron spin and more in nuclear physics. Also put forth the concept of neutrinos.

L. De Broglie
Introduced the concept of electron energy levels as increments of wavelength giving explanation for Bohr's mechanical energy states. Later explained mathematically by Schrödinger.

W. Heisenberg
Heisenberg's Uncertainty Principle which states that the higher precision in the value of the current position of a particle the lower the precision of its instantaneous momentum and the reverse. You cannot know both the precise location and precise momentum of a particle.

P.A.M. Dirac
Using clever calculus, H. Minkowski space, and the work of de Broglie and Pauli, Dirac was able to determine a general equation linking quantum theory and relativity.

E.Fermi
Fermi was able to describe beta particle decay and made other contributions in the area of nuclear reaction, eventually his work was used in the Manhattan Project during World War II.

H. Yukawa
Explained interaction between protons and neutrons in the nucleus of an atom by introducing a new particle called a meson.