Paul Langevin (1872 -- 1946)

Paul Langevin was born in Paris on 23 January 1872. He attended the Ecole Lavoisier and the Ecole de Physique et de Chimie Industrielles, where he was supervised by Pierre Curie (1859-1906) during his laboratory classes. In 1891 he entered the Sorbonne, but his studies were interrupted for a year in 1893 by his military service. In 1894, Langevin entered the Ecole Normale Superieure, where he studied under Jean Perrin (1870-1942). Langevin joined the Collage de France in 1902, and was made Professor of Physics there in 1904, a post he held until 1909 when he was offered a similar position at the Sorbonne. Contemporary to Marie Curie, Albert Einstein and Hendrik Lorentz, he was noted for his work on the molecular structure of gases, analysis of secondary emission of X-rays from metals exposed to radiation and for his theory of magnetism. He suggested that the alignment of molecular moments in a paramagnetic substance would be random in the absence of an externally applied magnetic field, but would be non-random in its presence. The greater the temperature, however, the greater the thermal motion of the molecules and thus the greater the disturbance to their alignment by the magnetic field.

Langevin further postulated that the magnetic properties of a substance are determined by the valence electrons, a suggestion which influenced Niels Bohr (I885-1962) in the construction of his classic model describing the structure of the atom. He was able to extend his description of magnetism in terms of electron theory to account for diamagnetism. He showed how a magnetic field would affect the motion of electrons in the molecules to produce a moment that is opposed to the field. This enabled predictions to be made concerning the temperature-independence of this phenomenon and furthermore to allow estimates to be made of the size of electron orbits.

He published his work on the atomic theory of Para magnetism in 1905. In the same year Albert Einstein correctly identified Brownian motion (such motion, visible only under a microscope, is the incessant, random movement of micrometers-sized particles immersed in a liquid) as due to imbalances in the forces on a particle resulting from molecular impacts from the liquid. Shortly thereafter, Langevin formulated a theory in which the minute fluctuations in the position of the particle were due explicitly to a random force. Langevin's approach proved to have great utility in describing molecular fluctuations in other systems, including nonequilibrium thermodynamics.

Langevin and Einstein in 1911

In the later years, Langevin became increasingly involved with the study of Einstein's work on space and time. He was a firm supporter of the theory of the equivalence of energy and mass. Einstein later wrote that Langevin had all the tools for the development of the special theory of relativity at his disposal before Einstein proposed it himself and that if he had not proposed the theory, Langevin would have done so.

Lorentz, Einstein and Langevin in 1927

Langevin was responsible for some of the most important work on piezoelectricity and on piezoceramics for which he was generally remembered. He was the inventor of the underwater Sonar for submarine detection during World War I, where his theories and researches were extensively utilized by the French and the Americans. In 1916 he was able to obtain echoes from the bottom and from a sheet of metal at a distance of 200 meters. In 1917 Langevin started to use the piezoelectric effect, rather than the electrostatic projector and carbon-button microphone used in 1916. He also started the use of vacuum tube amplifiers in underwater sounding equipment, this is thought to be the first use of electronics in this manner. With this new technology echoes were received from a submarine for the first time, in 1918, as deep as 1500 meters. Their transducer was a mosaic of thin quartz crystals glued between two steel plates (the composite having a resonant frequency of about 50 KHz), mounted in a housing suitable for submersion. Working on past the end of the war, they did achieve their goal of emitting a high frequency "chirp" underwater and measuring depth by timing the return echo. The strategic importance of their achievement was not overlooked by any industrial nation, however, and since that time the development of sonar transducers, circuits, systems, and materials has never ceased.

After world war I his echo sounding devices were employed in many French ocean-liners, starting with the *Ile de France* in 1928. He was soon arrested by the Nazis for his outspoken antifascist views. He was first imprisoned in Fresnes, and later placed under house arrest in Troyes. The execution of his son-in-law and the deportation of his daughter to Auschwitz (which she survived) forced Langévin to escape to Switzerland in 1944. He returned to Paris later that year and was restored to the Directorship of his old school, but died soon after, in Paris on 19 December 1946.

The modern ultrasonics era arose from Professor Langevin's 1917 invention of the quartz sandwich transducer for underwater sound transmission in submarine detection. Intense ultrasound's physical effects had not gone unnoticed in the first decade of modern ultrasonics. Langevin's tests with quartz plate transducers had resulted in killing fish in the beam of sound. Professor Van Dyke had observed in 1924 the searing of skin when a resonant quartz bar was touched, the explosive atomization of water drops from the end of the rod and friction alleviation between a metal surface and the vibrating quartz. Nevertheless, no steps were taken to investigate these early observations more fully.

Among observers of Langevin's work was Professor R. W. Wood, an American physicist from Johns Hopkins University. Already famous for his work in optics and spectroscopy, and for his classic book "Physical Optics," he was also known as a brilliant lecturer and a writer of popular fiction and verse. With U.S. entry into WW I, Professor Wood was commissioned an Army Major and assigned to the Bureau of Inventions in Paris, where he devoted particular attention to the work of Langevin. Wood later noted how the contact with Langevin had made a strong impression:

"It was my good fortune during the war to be associated for a brief time with Prof. Langevin during his remarkable developments. At the arsenal at Toulon I witnessed many of the experiments with the high power generators. One was mounted in a large wooden tank filled with sea water, and when the Poulsen arc was started and the frequency adjusted for resonance the narrow beam of supersonic waves shot across the tank causing the formation of millions of minute air bubbles and killing small fish which occasionally swam into the beam. If the hand was held in the water near the plate an almost insupportable pain was felt, which gave one the impression that the bones were being heated."

Another wartime meeting that proved essential to the invention of power ultrasonics occurred when Professor Wood met Alfred L. Loomis at the Aberdeen Proving Grounds. Loomis, a successful lawyer, was directing Aberdeen research as an Army Major and invented, during this time, the "Loomis chronograph" for measuring the velocities of shells. After the war, Wood pursued other areas of war research and returned to his work in optics and spectroscopy, with his interests in ultrasonics remained dormant for several years. Loomis, following the war, entered investment banking, amassing a personal fortune during the 1920s. However, his interest returned increasingly to scientific research and, in 1924, Loomis renewed the wartime acquaintance with Wood and offered to collaborate and underwrite any joint research ventures. In 1926, Wood told Loomis of Langevin's experiments and suggested the subject offered a wide field for research in physics, chemistry, and biology.

With a high power General Electric vacuum-tube oscillator and a quartz plate transducer immersed in an oil-filled dish, experiments began in Loomis's garage in Tuxedo Park, New York. As research expanded, Loomis purchased a nearby mansion, converting it into his well-known Tuxedo Park Laboratory. The huge vacuum tubes, a large bank of oil condensers and an oversize variable condenser and step-up induction coil made the ultrasonic apparatus an imposing affair. Vibrations of 200-500 kHz were transmitted through the oil bath into glass vessels or rods immersed in the bath, achieving a range of spectacular effects that included:

radiation pressures of sufficient magnitude to support 150 g and to raise a pronounced mound of oil above the transducer; intense searing of the skin by the vibrating glass rod and the burning of wood chips and the etching and drilling of glass pressed against the tips of vibrating glass rods; heating of liquids and solids and the formations of emulsions and fogs; biological effects including rupturing of red blood cells, killing of cellular organisms, and harmful to lethal effects on fish, frogs, and mice; observations of chemical reactions and crystallization and flocculation of particles suspended in a liquid. These pioneering results could be taken as a present-day litany of ultrasonic achievements. Wood and Loomis also made observations of the modal patterns of rods, tubes, and plates and gave some of the first experimental data on phase velocity in rods and disks. Another first occurred when they made an ultrasonic horn by drawing down a glass tube to a tapered point to concentrate the energy at the point of application. Publication of these results started avenues of work being exploited to the present day.

Professor Wood did not continue work in ultrasonics, but returned to optics and spectroscopy. Aside from a 1939 "supersonics" monograph, in a scientific career spanning a half-century, this was to represent his involvement with ultrasonics. Loomis continued with other collaborators in research on the chemical effects of ultrasound while maintaining his interest in precision time measurement and other scientific areas. Backed by a private fortune, he was a 20th century patron of the sciences. In the years ahead, Loomis played an important role in founding other major laboratories and in stimulating World War II radar research.