

Heisenberg, Bohr, and the Bomb

Michael Frayn's play *Copenhagen* concerns two Nobel Prize-winning physicists, Niels Bohr (who was Danish) and Werner Heisenberg (who was German). Their work together from 1924 to 1927 laid the foundation for much of 20th century atomic physics. Less happily, their work, and that of other physicists of the period, also laid the foundation for the development of nuclear weapons.

Niels Bohr



Niels Bohr, born in 1885, completely transformed our view of the atom and of the world. Realizing that classical, Newtonian physics doesn't work when things are atom-sized or smaller, he remodeled the atom so electrons occupied "allowed" orbits around the nucleus while all other orbits were forbidden. In doing so, he founded quantum mechanics

Bohr received the 1922 Nobel Prize in Physics for his work on atomic structures, and he would continue to come up with revolutionary theories. He worked with Werner Heisenberg and other scientists on a new quantum mechanics principle connected to Bohr's concept of complementarity. The concept asserted that physical properties on an atomic level would be viewed differently depending on experimental parameters, hence

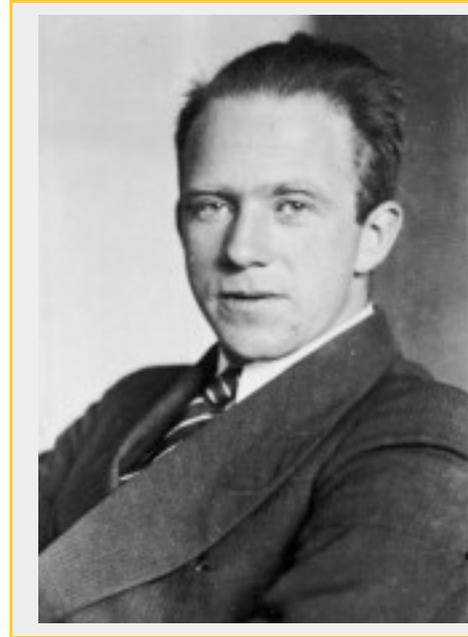
explaining why light could be seen as both a particle and a wave, though never both at the same time. Bohr would come to apply this idea philosophically as well, with the belief that evolving concepts of physics deeply affected human perspectives.

With Adolf Hitler's rise in power, Bohr was able to offer German Jewish physicists refuge at his institute in Copenhagen, which in turn led to travel to the United States for many. After Denmark was occupied by Nazi forces, the Bohr family escaped to Sweden. Bohr then worked with the Manhattan Project in Los Alamos, New Mexico, where the first atomic bomb was being created. Because he had concerns about how the bomb could be used, he called for future international arms control and active communication about the weapon among nations—an idea met with resistance by Winston Churchill and Franklin D. Roosevelt. He died in 1962.

Werner Heisenberg

Born in 1901, Werner Heisenberg was a German theoretical physicist who made foundational contributions to quantum theory. He was awarded the Nobel Prize in Physics in 1932 "for the creation of quantum mechanics."

From 1924 to 1927, Heisenberg lectured at the University of Göttingen and conducted research with Bohr at the University of Copenhagen. It led to the uncertainty principle, which states that the values of certain pairs of variables cannot both be known with complete precision. For example, if a particle is forced to take on a specific, precise position, then the particle's speed cannot be precisely defined (and vice versa).



When Hitler became Chancellor of Germany in 1933, some of the leading German theoretical physicists, including Heisenberg, found themselves attacked and ostracized. Heinrich Himmler, head of the SS, called him a "white Jew" who should be made to "disappear." But Heisenberg fought back with an editorial and a letter to Himmler, and the matter was eventually resolved.

In 1939, Heisenberg became one of the principal scientists leading research and development in the German nuclear energy project, and he travelled to German-occupied Copenhagen in 1941 to lecture and discuss nuclear research and theoretical physics with Bohr in 1941. This was the meeting explored in the play *Copenhagen*. He was asked by the Nazi administration to direct German research. His ambiguous role in the German nuclear project caused him to be a controversial figure for the rest of his life. He died in 1976.

World War II Nuclear Weapons Programs in the U.S. and Germany

In the U.S., following a letter to President Roosevelt from Albert Einstein, probably the most renowned physicist in the world, the U.S. began work on the Manhattan Project, a huge, well-financed crash program to develop the atomic bomb.

With a scientific headquarters at Los Alamos, New Mexico, and massive industrial complexes in Hanford, Washington, and Oak Ridge, Tennessee, the Manhattan project succeeded in successfully testing an atomic bomb in the spring of 1945. The atomic bombings of Hiroshima and Nagasaki, Japan, followed in the summer of 1945.

In contrast, the German nuclear program was disorganized and abortive. It appears that the German nuclear weapons project as a whole did not have the same sense of urgency that characterized the American effort. In addition, the German project was bureaucratically fractured and cut off from international collaboration.

After a 1942 conference with Axis scientists, German minister for armaments and war Albert Speer concluded that reactor research should proceed, but that any bomb was unlikely to be developed in time for use in the war. Key materials were in short supply in Germany, and Allied bombing of the country's industry and transportation network made building anything on the scale of the American effort unlikely. There were also some critical scientific mistakes in the German research. Some accounts have presented Heisenberg as simply incompetent; others, conversely, have suggested that he deliberately delayed or sabotaged the effort.