

## **Niels Bohr's Life in and Around Physics**

Niels Bohr (1885-1962) stands next to Albert Einstein (1879-1955) as a creator of modern physics. Unlike Einstein's relativity, however, Bohr's atomic model and the principles he invented to produce a better one, which materialized in Werner Heisenberg's matrix mechanics (1925), have long since disappeared from the tool kit of physicists. Yet his manner of thinking guided a generation of first-rate theorists, which included Max Born and Wolfgang Pauli as well as Heisenberg, and enabled him to defeat Einstein in a long controversy over the interpretation of the quantum world.

### **Objective and method**

The main work of HPS 156 is to investigate the apparent paradoxes of quantum theory and the creative process in science by studying Bohr's unique style of reasoning. The subject divides naturally into three parts:

- a survey of the wide background to Bohr's invention of the quantized atom;
- an account of the development of atomic theory under his guidance through the creation of quantum mechanics;
- an analysis of Bohr's concept of complementarity and its applications beyond physics.

At its last meeting, the class will watch and discuss Michael Frayn's play *Copenhagen*, which dramatizes a meeting between Bohr and Werner Heisenberg in German-occupied Copenhagen in 1942 shortly before Bohr escaped to Britain and the US to participate in the atomic-bomb project. As this material suggests, the course deals not only with the work of atomic physicists, but also with the social and political contexts in which they did it.

### **Assignments**

A few pleasant exercises are necessary to begin to master this material:

- studying interesting assigned texts;
- participating in class discussion;
- writing a paper for each of the three sections into which the subject matter divides.

Assigned readings will be posted on the class website beginning 15 March. They are designated "A," "B," through "K" in the Schedule that follows.

## Schedule

Week 1. Physics around 1900: A century of progress and a decade of trouble  
Readings: K, pp. 1-35, and Wikipedia article on Bohr; in addition, a glance at general references, e.g., Moore, 3-47, Pais, 32-51, 97-113, or Rozenal, 11-73, would be useful.

Week 2. World pictures and their artistic theorists  
Reading: K, pp. 36-68.

Week 3. Niels Bohr: a big man from a small country  
Reading: A

Week 4. "The Bohr Atom": an exercise in creative incoherence  
Reading: B. *Problem set 1 due.*

Week 5. Reception of Bohr's creation  
Readings: C, K, pp. 69-83.

Week 6. The correspondence principle and the old quantum theory  
Readings: D, D\*, E

Week 7. Quantum mechanics and complementarity  
Readings: F, F\*. *Problem set 2 due.*

Week 8. Physics philosophy beyond physics  
Reading: I

Week 9. Arguments with Einstein  
Readings: G, H.

Week 10. *Copenhagen*: a dialogue of the dead  
Reading: J

Week 11. *Problem set 3 due.*

## Key to readings

A. Letters to Harald Bohr, 29 Sep, 4 and 23 Oct 1911, 27 and 28 May, 12, 19, and 23 June, and 23 Dec 1912, in Niels Bohr, *Collected works [CW], 1* (Amsterdam: North Holland, 1972), pp. 519 ff.

B. "Om brintspektret." *Fysisk tidsskrift*, 12 (1914), 97-114; in English in Bohr, *The theory of spectra and atomic constitution* (Cambridge: Cambridge University Press, 1922, 1924), pp. 1-19.

C. Letter from Harald Bohr, Fall 1913, in *CW*, 1, 567; and letters to and from Hevesy, 7 Feb, 6 Aug, and 23 Sep 1913, to Moseley, 16 and 21 Mar, and 16 Oct 1913, and to Oseen, 28 Sep 1914. In *CW*, 2 (1981), pp. 529 ff.

D. "The structure of the atom." *Nature*, 112 (1923), 29-44. [Bohr's Nobel lecture].

D\*. Editorial comment on D.

E. [with H.A. Kramers and J. C. Slater] "The quantum theory of radiation." *Philosophical magazine*, 47 (1924), 785-802.

F. "The quantum postulate and the recent development of atomic theory. *Nature*, 121:supplement (1928), 580-590. [Como talk on complementarity]. Also in Bohr, *Atomic theory and the description of nature* (Cambridge: Cambridge University Press), pp. 52-91.  
F\*. Editorial comment on F.

G. "Discussions with Einstein on epistemological problems in atomic physics." In P.A. Schilpp, ed. *Albert Einstein, philosopher-scientist*. Evanston, Ill.: Library of Living Philosophers, 1949. Pp. 201-241. Also in Bohr, *Atomic physics and human nature* (New York: Wiley, 1958), pp. 32-66.

H. "Can quantum-mechanical description of reality be considered complete?" *The physical review*, 48 (1935), 696-702. [Answer to Einstein-Podolsky-Rosen and anticipation of Bell].

I. "Light and life." *Nature*, 131 (1933), 421-3, 457-9. Also in *Atomic physics and human knowledge*, pp. 3-12.

J. "Open letter to the United Nations." Copenhagen: Schultz, 1950.

K. J.L. Heilbron, "Physical science around 1900": Background, 1-35; Ray physics and chemistry, 36-51; Atomic structure, 52-68; Science in World War I, 69-83. [English originals of articles in *La storia della scienza*, vol. 8 (Rome: Enciclopedia italiana, 2004)].

## General references

Bohr, Niels. *Collected works*. 12 vols., Amsterdam: North Holland, 1972-2008.

French, A.P., and P.J. Kenedy. eds. Niels Bohr. *A centennial volume*. Cambridge: Harvard University Press, 1985.

Moore, Ruth. *Niels Bohr*. New York: Knopf, 1966.

Pais, Abraham. *Niels Bohr's times*. Oxford: Oxford University Press, 1991.

Rozental, S. *Niels Bohr. His life and work as seen by his friends and colleagues*. Amsterdam: North Holland, 1967.