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Ernst Ising—Physicist and Teacher

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The Ising model is one of the standard models in statistical physics. Since 1969 more than 13800 publications using this model have appeared. In 1997 Ernst Ising celebrated his 97th birthday. Some biographical notes and milestones of the development of the Ising model are given.

KEY WORDS: History of statistical physics; Ising model.

Ernst Ising was born on May 10, 1900 in Köln (Cologne, Germany), the son of the merchant Gustav Ising and his wife Thekla, nee Löwe. The family moved to Bochum (Westphalia). Ernst Ising completed the Gymnasium in Bochum in 1918. Shortly after that he had to do a brief military training. In 1919 he started studying mathematics and physics at the University of Göttingen, and he continued his studies in Bonn and Hamburg. In Hamburg Wilhelm Lenz (1888–1957) suggested to Ising that he turn to theoretical physics. Under Lenz's guidance Ising began investigating a model of ferromagnetism which his supervisor had introduced in 1920.[1] In his dissertation[2] Ising studied the special case of a linear chain of magnetic moments, which are only able to take two positions, "up" and "down," and which are coupled by interactions between nearest neighbors. He showed that spontaneous magnetization cannot be explained using this model in its one-dimensional version but erroneously he applied this result also to the three-dimensional case.[3]

After receiving his doctor's degree Ising went to Berlin and worked from 1925 to 1926 in the patent office of the Allgemeine Elektrizitätsgesellschaft (AEG). He was not satisfied with this job and decided to become a

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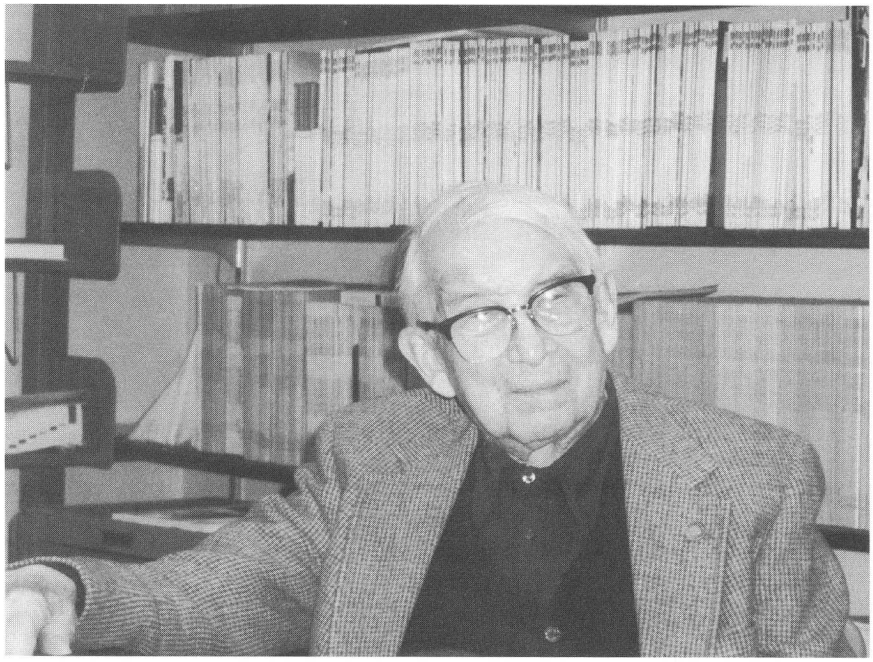

Fig. 1. Ernest Ising. Photograph taken in the Library of the Departments of Natural Sciences, Bradley University, Peoria (IL) on 11 March, 1996.

teacher. For a year he worked at the famous boarding school in Salem in South-Baden (near the lake Constance). In 1928 he returned to Berlin University to study philosophy and pedagogy. In 1930 he passed the state examinations before the school board in higher education. In the same year he married Johanna Ehmer, who held a doctorate in economics. The couple went to Strausberg near Berlin, where Ernst Ising got a teaching position at a high school as "Studienassessor" (in Germany, a holder of a higher civil service post who has passed the necessary examinations but has not yet completed his probationary period). Later he was transferred to Crossen on the river Oder (now Krosno Odrzańskie in Poland) to fill in for an ill colleague.

Just after Hitler came to power in January 1933, Jewish citizens were dismissed from their jobs as civil servants. Consequently, Ernst Ising lost his position on March 31st, 1933. For one year he was unemployed, except for a short stay in Paris at a school for immigrant children. In 1934 he found a new job as a teacher at a boarding school for Jewish children in Caputh near Potsdam. This school was founded by the progressive social educationalist Gertrud Feiertag (1890–1943?). Next to the main building

was Albert Einstein's summer house. When in 1932 Einstein went to U.S.A., this house was rented from him for additional classes. The number of students increased in the following years, because Jewish children had been expelled from public schools. In 1937 Ising became the headmaster of the school. In this position on November 10, 1938 he experienced the devastation of his school building by inhabitants and children of the village who had been incited as part of the great pogrom against the Jewish population in Germany.

In the beginning of the year 1939 Ernst and Johanna Ising traveled to Luxembourg with the plan to emigrate to the United States of America. But at that time there was a quota of immigration to the U.S.A. and so it was impossible for them to fulfill their plan. On Ising's fortieth birthday the German army occupied Luxembourg. The U.S. consulates were closed just before the waiting time for emigration was over. Ising and his family survived the war. From April 1943 until the liberation in autumn 1944, he was forced to work for the German army, dismantling the rails of the Maginot line in Lorraine.

Two years after the end of the war Ising left Europe on board a freighter to the U.S.A. He got a job as a teacher at the State Teacher's College in Minot (N.D.). From 1948 till 1976 he was Professor of Physics at Bradley University, Peoria (IL), earned an honory doctorate from this university in 1968, and was named "Outstanding Educator of the Year 1971." Since 1953 Ernest Ising has been a U.S. citizen. Before and after his retirement he traveled much and visited all states of the U.S.A and many countries all over the world.

Now Ising lives in Peoria. Recently he celebrated many jubilees: among them were the 70th anniversaries of his doctoral degree and of the appearance of his publication,[3] and his 65th wedding anniversary.

Ising became aware of the first citation of his paper by Heisenberg,[4] who introduced the quantum mechanical exchange interaction to describe ferromagnetism. Later Ising was completely shut off from scientific life and communication for a long time. It was not until 1949 that Ising found out from the scientific literature that his paper had become widely known.

The main drive for calling the model "Ising model" seems to stem from R. Peierls' publication, "On Ising's Model of Ferromagnetism."[5] Peierls considered boundary lines which separate "up" and "down" spin regions in a two-dimensional square Ising lattice. By estimation of an upper limit for the total length of closed boundaries he could show that, at sufficiently low temperatures, only a small fraction of all spins are enclosed by boundary lines. Consequently, the majority of spins must have the opposite sign leading to spontaneous magnetization of the system. N. G. van Kampen, M. E. Fisher, S. Sherman and others found later that in Ref. 5 summations over

the lengths of boundaries were incorrectly extented to infinity for finite systems, cf. Refs. 6 and 7. Finally, Griffiths has remedied this defect in 1964 by a modification of Peierls' proof.[7] Peierls pointed out in 1966 that his original argument is not influenced by the found error, because it only leads to an overestimation of the length of boundary lines and the rest remains valid.[8]

The most striking success of the model is accompanied by the search for the phase transition between the ferromagnetic and the paramagnetic state, cf. Ref. 6. The actual breakthrough came from the findings of various authors[9-11] which say that a matrix representation of the problem can be introduced in such a way that the partition function can be related to the largest eigenvalue of this matrix. Kramers and Wannier[9] calculated the numerical value for the Curie temperature of the two-dimensional Ising model, whereas the exact and complete solution was first given by Onsager.[12]

Today the Ising model is a widely used standard model of statistical physics. Every year about 800 papers which apply this model are published; problems regarding neural networks, protein folding, biological membranes, social imitation, social impact in human societies and frustration are among them.

In this contribution some biographical notes on the life and work of E. Ising are given and the early history of the Ising model is mentioned. Further biographical sources can be found in Refs. 6, 13–17.

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REFERENCES

1. W. Lenz, *Phys. Zeitschrift* **21**:613 (1920).
2. E. Ising, Beitrag zur Theorie des Ferro- und Paramagnetismus (Thesis, Hamburg, 1924), in German.
3. E. Ising, *Zeitschrift f. Physik* **31**:253 (1925).
4. W. Heisenberg, *Zeitschrift f. Physik* **49**:619 (1928).
5. R. Peierls, *Proc. Cambridge Phil. Soc.* **32**:477 (1936).
6. S. G. Brush, *Rev. Mod. Phys.* **39**:883 (1967).
7. R. B. Griffiths, *Phys. Rev.* **136**:A437 (1964).
8. R. E. Peierls, *Math. Rev.* **32** (1966), no. 7103, p. 1206.
9. H. A. Kramers and G. H. Wannier, *Phys. Rev.* **60**:252 (1941).
10. E. Montroll, *J. Chem. Phys.* **9**:706 (1941); **10**:61 (1942).
11. R. Kubo, *Busseiron Kenkyu* **1**:1 (1943), in Japanese.

12. L. Onsager, *Phys. Rev.* **65**:117 (1944).
13. L. Fry, *The Isings and the 20th Century* (Hilltopics, Bradley University, Peoria, October 1991), p. 4.
14. H. Feidel-Mertz and A. Paetz, Ein verlorenes Paradies (dipa, Frankfurt/M., 1994), in German.
15. S. Kobe, *Physikalische Blätter* **51**:426 (1995), in German.
16. S. M. Bhattacharjee and A. Khare, *Current Science (India)* **69**:816 (1995).
17. J. Ising, Walk on a Tightrope or Paradise Lasted a Year and a Half, 1986, unpublished.