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Rudolf Peierls – Physicist *par excellence* (1907–1995)

Rudolf Peierls, one of the remarkable theoretical physicists of the 20th century, died on 10 September 1995. We reproduce on **page 707** the Rutherford Memorial Lecture which he delivered in India in 1987. Also reproduced in box **(page 709)** are the introductory remarks made by the present writer before Peierls delivered an Academy lecture, which give a flavour of the man and the scientist.

The following account has been gleaned mostly from articles written about Peierls.

Peierls was one of the physicists of his generation who had an enormous influence over the development of the subject and also over world affairs. Apart from his scientific contributions, Peierls will be remembered for the definitive role he played in the key scientific problem of this century – the atom bomb. When the Second World War started, it was a common view amongst many knowledgeable physicists that making a uranium bomb was possible. The design of the bomb, however, hit a stumbling block when it was found that the amount of uranium required was impossibly large to be contained in a reasonable volume. The way round this obstacle came when Otto Frisch asked Rudolf Peierls whether the isotope ^{235}U alone could be used to make an atom bomb. Peierls made the calculation on the proverbial back of the envelope (which one guesses must have been quite large) and got the surprising result that less than a kilogram of ^{235}U would be quite sufficient for making a very 'effective' bomb. The method and technology of separating ^{235}U from ^{238}U by gaseous diffusion was also worked out in detail. These investigations gave rise to the famous Frisch–Peierls Memorandum that was sent to the British Government and the document was immediately classified as top secret. The two authors who were then enemy aliens in England did not have access to the document they themselves had written. But soon good sense prevailed. The document was then sent to the United States. Peierls was invited over to Los Alamos and worked with Oppenheimer on the atomic bomb. The rest is history. The memorandum also established the devastation that such a bomb could cause. It was so great that Peierls never believed that there could ever be a limited nuclear war. He therefore took great interest in nuclear arms control and the Pugwash movement of nuclear disarmament.

His experience and insight combined with great honesty and clarity of vision placed him amongst the most authoritative commentators in his field. Peierls' name is almost synonymous with atomic history and we are fortunate that in his long life he has published a wide range of papers dealing with this science and the personalities involved in it and the various related issues of physics.

Peierls was born in Berlin of a Jewish father and a Roman Catholic mother. He was baptized a Protestant. It is of some interest that he has written a balanced article on 'The Jew in 20th century physics'. He went to the Humboldt school in Berlin and sampled several universities in getting his first degree. To quote his reputed student Sam Edwards 'To Berlin (where Max Planck's lectures were amongst the worst in the world)'; to Munich 'where Arnold Sommerfeld's were amongst the world's best' and to Leipzig where he gained his doctorate working with Heisenberg. His post-doctoral years took him to Europe, notably to Zurich from 1929 to 1932 where he was Wolfgang Pauli's assistant (Peierls has a large store of Pauli stories, some of which he has published). He also went to the USSR where he met Eugenia (who was also a physicist) and the year after that he went to Leningrad to marry her – a courageous act since the couple had a long battle to get her out of the country. There in the early thirties, he and Landau put down their thoughts on quantum chromodynamics.

The work for which Peierls is best known from this period is on the physics of phonons. He actually established the concept of 'zones' in reciprocal space before Leon Brillouin, established the Boltzmann transport equations for phonons and discovered the Umklapp process whereby the analogue of momentum conservation in a lattice occurs modulo a reciprocal lattice vector.

Rudolf Peierls in Bangalore

His many papers on electrons in metals have passed deeply into the literature, especially those on the conductivity of the solids in a magnetic field and the concept of holes in the electronic structure of solids.

From Zurich he went to Rome, to Cambridge and then onto Manchester where a fund had been set up for refugees. He and Hans Bethe found themselves together there. In answer to a question by Chadwick they published a definitive paper on the photodisintegration of the deutron. Their paper on the statistical mechanics of alloys still serves as a basis for improving mean field theories of structural phase changes in complex alloys. At Cambridge, he did notable work on superconductivity and liquid helium. He and P. G. L. Kapoor gave a general dispersion formula for nuclear reactions using complex boundary conditions on the spherical nuclear surface. In 1937 he accepted the Chair in the University of Birmingham and joined as the head of the mathematics and theoretical physics departments. In 1964 he came to Oxford and remained there till the end of his life.

On an earlier visit to India, Peierls made it a point to attend a seminar given by C. V. Raman explaining his theory of the dynamics of crystal lattices, a subject on which there was much controversy between Raman and Max Born. Peierls then wrote a paper, which was published in India, pointing out the error that Raman had committed. When Arthur Edington, the great astrophysicist, was ridiculing Subrahmanyan Chandrasekhar's views, Peierls was one of the few who published a paper (in the *Royal Astronomical Society*) that Edington was wrong. Peierls is particularly remembered by a large community of theoretical physicists from all over the world for the enormous support he gave to the progress of theoretical physics and who turned his hand to any problem in physics. When I had to teach dislocation theory to undergraduates at the Indian Institute of Technology, I came across Peierls' name in connection with the forces that moved dislocations. I wondered how a person so involved in other areas got to work on dislocation physics. As Peierls explained, he knew nothing about dislocations but when Orowan was stuck on the problem of calculating the force required to move a dislocation he could give a solution, as Peierls knew classical elasticity due to the grounding he received by listening to Arnold Sommerfeld's lectures. This was later developed further by Nabarro and is now known as the Peierls–Nabarro force.

Peierls was one of the great generalists and had an authoritative grasp of almost every aspect of theoretical physics. He took his teaching responsibilities very seriously. He disdained embellishments and encouraged students to find the clearest and simplest route to an answer. It is estimated by Hans Bethe that scores of the better theoretical physicists of England were trained under Peierls during his tenure at Birmingham and Oxford. He had a distinctive style in physics. His contributions to education in physics and nuclear arms control and also East–West understanding will always be remembered. Peierls would like to be known as a physicist who could turn his hand to any problem especially because theoretical physicists in the post-war period had a tendency to specialize in either nuclear physics or the fundamental particle science or the theory of solids. Peierls refused to do this and wanted to be a generalist. He accepted research students in all the three fields and published papers on the application of quantum mechanics to solids and to nuclei. Both at Oxford and at Birmingham, Peierls had an open house. He always seemed to find ways of supporting scientists and his wife Eugenia was a kind, hospitable and decisive organizer of the visitors. Their large house was the centre of innumerable dinners and parties in which they and their four children enjoyed the company of many remarkable people. Anyone could go to these parties and gatecrashing was the order of the day as that was the best method of meeting socially the better physicists who visited England. According to Lady Eugenia Peierls, who died 5 years before Peierls, physicists could be divided into two classes: golfers who single-mindedly pursued a lonely path towards a clear goal (Dirac was the archetypical example) and tennis players who made progress by batting ideas back and forth. Peierls is an example of the latter who not only played the game superbly and incomparably but always brought out the best in his opponent.

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