Nye, John Frederick

(1923–2019)

Michael Berry

https://doi.org/10.1093/odnb/9780198614128.013.90000381367
Published online: 13 April 2023

Nye, John Frederick (1923–2019), physicist, was born at 67 Brunswick Place, Hove, Sussex, on 26 February 1923, the younger son of Haydn Percival Nye (1881–1977), chartered surveyor, and his wife, Jessie Mary (Mamie), *née* Hague (1879–1950), then of 11 Wilbury Villas, Hove. His father had earned the MC in the First World War while serving as a lieutenant in the Royal Engineers, and was a member of the Catholic Apostolic church. Mamie worshipped at the Church of England, and John and his brother, Peter (*b.* 1921), divided their Sundays between 'Daddy's church' and 'Mamie's church'.

Nye's secondary education was as a boarder at Stowe School, where the natural and architectural beauty of the estate, and the inspiration of a teacher specializing in optics and photography, sparked the characteristic visual emphasis of his subsequent physics research. In 1941 he moved to King's College, Cambridge, as an undergraduate, and completed a PhD there in 1948. After postdoctoral research in Cambridge and at the Bell Telephone Laboratories in New Jersey, in 1953 he moved to the physics department at the University of Bristol, where he remained for the rest of his working life. On 28 December 1953, in the chapel of King's College, he married Georgiana Wiebenson (*b.* 1926), daughter of Walter Ernest Wiebenson, building manager); an American, she had studied contemporary dance with the Martha Graham Company in New York. They had two daughters, Hilary (*b.* 1957) and Carolyn (*b.* 1963), and one son, Stephen (*b.* 1960).

Nye's major contributions to physics were in three areas: crystals, ice, and light. In crystals, his emphasis was on the defects that disrupt the regular arrangement of their atoms; in the spirit of his Bristol colleague Charles Frank he believed that 'Crystals are like people: it is their imperfections that make them interesting'. His first contribution to science, in 1947, was a collaboration with the Nobel prize-winner Sir Lawrence Bragg; they explored crystal defects with an analogue experiment, in which the atoms in a crystal were represented by a raft of bubbles. He was among the first to realize that for some purposes a crystal can be regarded as a gas of continuously distributed defects. This phase of his research culminated in his text *Physical Properties of Crystals* (1957); this was still in print at the time of his death, and was a uniquely accessible treatment of a difficult subject.

In glaciology, Nye made seminal contributions to understanding how ice flows. Most previous glacier theory had treated ice as a liquid with a very high viscosity. Nye's first paper, in 1951, took the more realistic model of ice as a perfectly plastic material: rigid until a certain stress was reached, and only then flowing. This led to theoretical predictions confirmed by observation. In 1958 he applied mathematics previously developed to explain movement of traffic on roads to explain also the occurrence of surges in glaciers and ice sheets. In 1960 he studied the response of glaciers and ice sheets to seasonal and climatic temperature changes, revealing why glaciers are sensitive indicators of climatic change, and leading to understanding how glaciers advance and retreat. Evidence of Nye's remarkable originality was his emphasis, in a 1970 paper on glacier sliding, on the fact that the rock bed contains irregularities on a wide range of scales, so it is impossible to separate roughness from geography. In envisaging a statistically self-similar distribution of heights, he anticipated the central idea in what later emerged as a major area of applied mathematics: 'fractal geometry'. Further work proposed a method for determining the movement of large ice sheets by detailed mapping of the radio echoes from the bed. This was the starting point of his original research in optics and electromagnetism.

Nye's research was not only theoretical. He was a valued team member on field trips and expeditions to the Alps, the Pacific north-west, and the South Pole. He served as president of the International Glaciological Society from 1966 to 1969, and in the latter year received its prestigious Seligman crystal ('awarded from time to time to one who has made an outstanding scientific contribution to glaciology so that the subject is now enriched').

Nye was always interested in the physics of light. *Physical Properties of Crystals* included a treatment of polarized light in anisotropic media. This was a pedagogical account of standard material, self-contained, and with the clarity that characterized all his writing. It was around 1970 that his original contributions to the understanding of electromagnetic waves, and light in particular, began, and continued for the rest of his life.

The spark that ignited this change in his scientific direction was the measurements of the thickness of ice sheets by radio echo-sounding. In this technique, a pulse was reflected from the bottom, and information about the underlying topography was obtained from the delay between emission and the reception of the first part of the echo, reflected from the rock directly below the source. Nye realized that the long tail of the echo was scattered by distant roughness. To investigate this in the laboratory, he devised a student project, in which the radio waves, of wavelength 5 m, were replaced by ultrasound, of wavelength 5 mm, and the roughness of the ice-rock interface was modelled by crinkled aluminium kitchen foil. This enabled the oscillations in the reflected wave to be studied in detail.

While moving the source-receiver, Nye noticed something unexpected: oscillations would separate and a new one would be born between them, or an oscillation would disappear. He realized what this implies for the geometry of the crests and troughs (wavefront surfaces) in the reflected wave: they can have edges, and the birth and death of oscillations happens when an edge encounters the detector. He understood that a wavefront with an edge resembles a defect disrupting the regularity of the crystal lattices he had studied earlier. Therefore he called the edges 'wavefront dislocations'.

In joint research with Michael Berry, it became clear that wavefront dislocations are a previously unrecognized fundamental feature of waves of all kinds. On the edges of wavefronts, the phase of the wave is undefined and the wave intensity is zero. Therefore wavefront dislocations are also 'phase singularities' and 'nodal lines'. The trajectories normal to the wavefronts, along which wave energy flows, circulate around the dislocation lines, so yet another term for them is 'wave vortices'. They are the most delicate features of waves, representing intricate geometry on scales much smaller than the wavelength.

The paper reporting this discovery was initially rejected by the Royal Society's anonymous referee, on the grounds that the calculations were too simple. But a second referee recognized simplicity as a positive feature, adding that the paper 'might have been written by Sir Geoffrey Taylor or even Lord Rayleigh or

Lord Kelvin, but seems to have escaped them' (Royal Society archives). This became Nye's most cited paper, and 'optical vortex theory', as it was later known, became a thriving area of what came to be called 'singular optics', described in several textbooks and review articles, and hundreds of papers.

Nye next turned his attention to optics on the coarsest scale, where a field of light is represented by a family of rays, and the singularities are the 'caustics', on which the light is focused. This ancient branch of optics had been reinvigorated in Bristol in the early 1970s, thanks to the mathematics of 'catastrophe theory', providing a library of the sometimes unexpected natural forms that caustics can take. Nye entered this field with detailed experimental and theoretical studies of lensing by water-drops deformed by gravity. These new focal structures are decorated by rich patterns of wave interference, and Nye contributed to this connection across optical scales, by providing much of the conceptual understanding, and experimental confirmation, in an analysis, with Berry and Francis Wright, of one such 'diffraction catastrophe'.

Light waves are electromagnetic, and possess the additional property of *polarization*. Here too Nye made a fundamental contribution, by identifying, theoretically and experimentally, together with Jo Hajnal, the two kinds of singular lines in typical light fields: where the polarization is purely circular, or purely linear. For the sensing technique they developed for microwaves, Nye and Hajnal were awarded the 1986 Metrology award by the UK's National Physical Laboratory.

In 1999 Nye summarized his central contributions to the three pillars of singular optics, namely the singularities of phase, caustics, and polarization, in his book *Natural Focusing and Fine Structure of Light*. He explained the physics and the mathematics, combining theory, computer simulation, and beautiful experimental photographs, with a clarity that cannot be improved upon. The underlying organizing principle, emphasized throughout, is that the singularities are natural, in the sense that they are stable under perturbation.

Those who worked closely with Nye—who was elected a fellow of the Royal Society in 1976—appreciated his decency and his scientific generosity: the epitome of the English scientific gentleman. His intellectual determination was perfectly balanced by his unfailing politeness. His intense curiosity persisted until the day before his death, at his home in Canynge Road, Clifton, Bristol, on 8 January 2019. His wife and three children survived him.

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