

# Physics 87

*The title page of Newton's Principia, published 300 years ago.*

87 seems an auspicious cycle for physics. This year has seen the first neutrino observation of a supernova and the development of a new class of superconductors which carry large currents at relatively high temperatures. It is also the centennial of several major events in the history of physics which have shaped our present understanding of the universe.

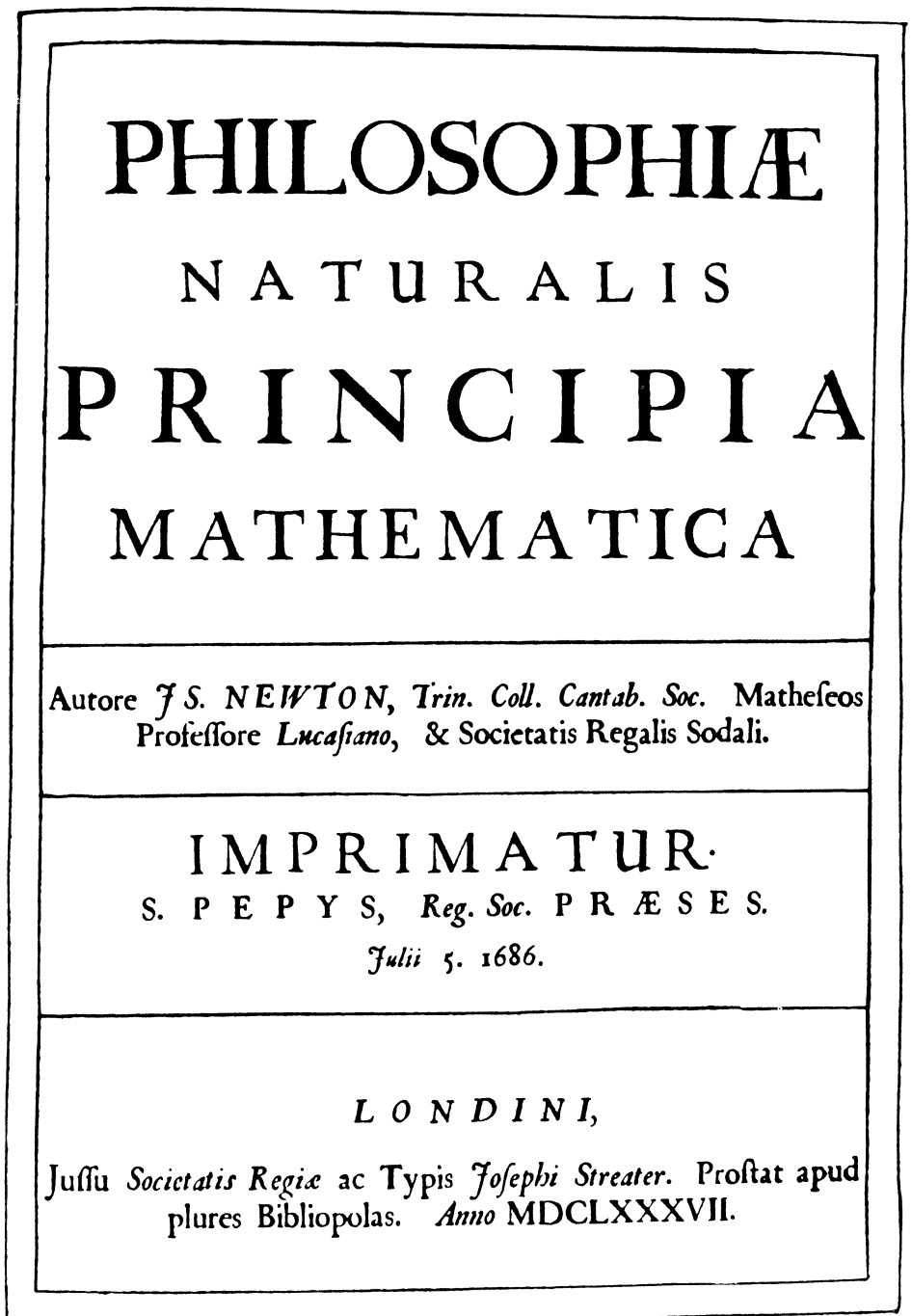
In 1687, Edmond Halley as Secretary of the Royal Society in London wrote to Isaac Newton in Cambridge to confirm that the latter's *Philosophiae Naturalis Principia Mathematica* was finally ready for publication.

In view of the Royal Society's lack of funds at the time, Halley had undertaken to publish the book at his own expense.

'Honoured Sr, I have at length brought your Book to an end, and hope it will please you. The last errata came just in time to be inserted. I will present from you the books you desire to the R. Society, Mr Boyle, Mr Pagit, Mr Flamsteed and if there be any elce in town that you design to gratifie that way; and I have sent you to bestow on your friends in the University 20 Copies, which I entreat you to accept.'

Two hundred years later, in Cleveland, Ohio, Albert Michelson and Edward Morley failed to detect any effect on the velocity of light due to the movement of its source, a puzzling null result which had to wait 18 years for an explanation by Einstein's revolutionary Special Theory of Relativity.

Also in 1887, Heinrich Hertz, then working in Karlsruhe, was especially busy discovering the electromagnetic radiation suggested twenty years earlier by Maxwell's equations. Not content with this single breakthrough, he



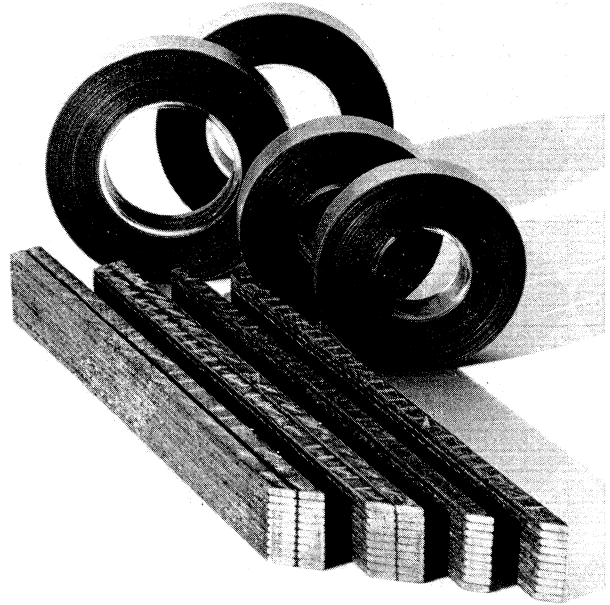
saw for the first time the photoelectric effect. For the explanation of this initial example of light waves behaving like particles, the world also had to wait until 1905 and the genius of Einstein.

Three centuries after the publi-

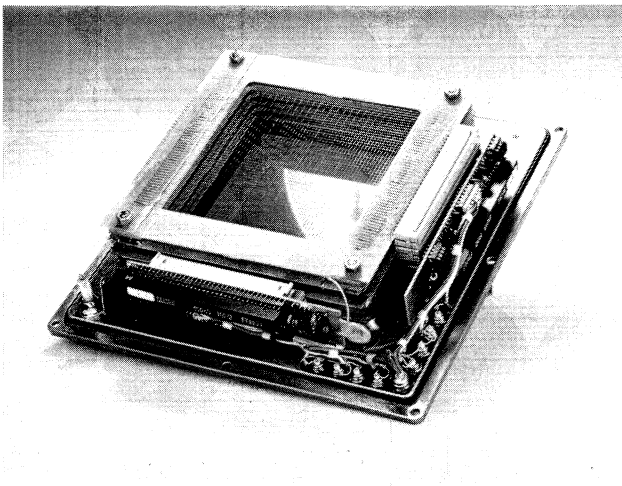
cation of Newton's masterpiece, Stephen Hawking and Werner Israel assembled a group of the world's foremost researchers in cosmology, relativity and particle physics for a commemorative meeting '300 years of Gravitation'

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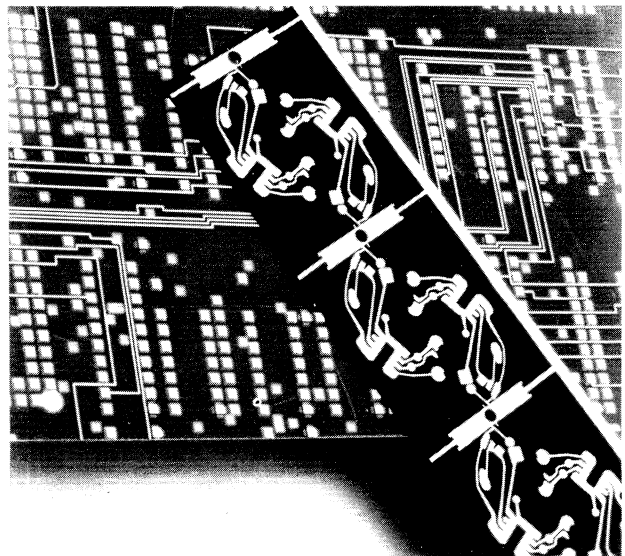
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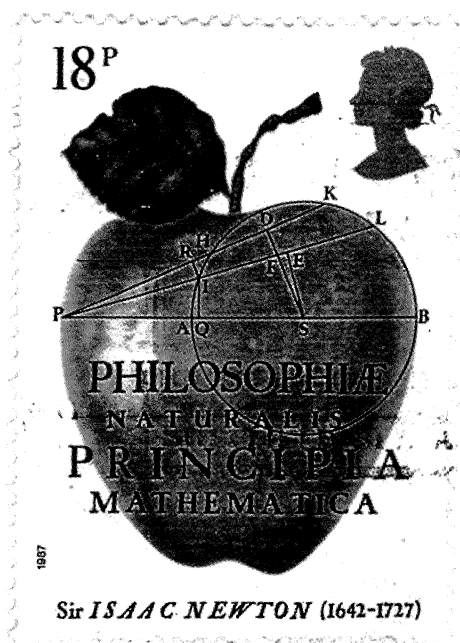
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UK postage stamp commemorating this year's tercentenary of the publication of Isaac Newton's 'Principia'.



in Cambridge earlier this year. In addition, Trinity College, Newton's home from 1661 to 1696, organized its own tribute, as did the Royal Society.

The papers presented at the Gravity 300 meeting have been published as a commemorative volume\*. Introducing the subject, Stephen Hawking claimed Newton's *Principia* to be 'probably the most important single work ever published in the physical sciences', and went on to explain how Newton was motivated by Halley to make clear how the elliptical orbits of the planets were due to an inverse square type force directed towards the sun, a result Newton had in fact worked out some years earlier but had not published.

In the *Principia*, Newton introduced the ideas of absolute time and absolute space, controversial concepts which nevertheless held fast until the advent of Einsteinian relativity more than two centuries later. In the book, Newton did not introduce his idea of 'fluxions' — a form of differential calculus he

developed to handle forces varying in magnitude and direction — preferring the historically acceptable geometrical approach, and leaving the door to calculus open for Leibniz.

In the preface to the first edition of *Principia*, Newton remarked 'I wish we could derive the rest of the phenomena of Nature by the same kind of reasoning for mechanical principles, for I am induced by many reasons to suspect that they may all depend on certain forces'. This hope has not been fulfilled, but, as Stephen Weinberg concludes in the book, 'we are working on it, very much in the Newtonian tradition: the formulation of increasingly comprehensive quantitative laws. From this high viewpoint, all that has happened since 1687 is a gloss on the *Principia*'.

The 1987a supernova came as a fitting monument to the tercentenary, underlining the importance of the classical theory and at the same time pointing to the future. Gravitation reflects both the sedate beauty of a classical theory and the turmoil of modern research, as exemplified by the contributions to the book.

### *Upsetting the ether*

The Michelson-Morley experiment was one of the big upsets of physics, undermining the considerable confidence that had built up in the ideas of the day and setting the scene for modern physics and the special theory of relativity almost twenty years later.

When the two American experimenters planned their epic study, electromagnetic radiation such as light was believed to travel through some invisible 'ether' that filled all

space. If so, radiation from a moving body should travel faster than radiation from a static source. To test this idea, Michelson and Morley built a superbly tuned instrument designed to compare the velocity of light moving in the same direction as the Earth with the velocity perpendicular to the Earth's motion.

After repeated attempts, they found no such evidence for the long-awaited ether. According to their precision experiment, the velocity of light looked to be independent of the velocity of its source. Working independently, Hendrik Lorentz in the Netherlands and George Fitzgerald in Ireland concluded that the paths travelled by the two perpendicular light beams had to depend on velocity. This empirical result was eventually set in context by Einstein, who showed that Newton's absolute benchmarks of space and time were only valid for everyday phenomena, and had to be rethought on the grander scale.

In 1907, Michelson became the first American to receive a Nobel Prize for scientific achievement, but to his death in 1931 remained a staunch opponent of quantum physics and relativity.

In Cleveland, Ohio, where the experiment took place, thirteen of the city's cultural and educational institutions joined in a city-wide six-month celebration entitled 'Light, Space and Time', encompassing the sciences, arts and humanities. Case Western Reserve University, where Michelson and Morley were based, played a leading role, with major symposia on

\* 300 years of Gravitation, edited by Stephen Hawking and Werner Israel, published by Cambridge University Press.

physics history and modern perspectives held during October.

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### *Hertzian waves*

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A pupil of Helmholtz, Heinrich Hertz made his initial mark on physics by justifying Maxwell's equations on theoretical grounds. With so much evidence building up to support the idea of electromagnetic radiation, he turned his attention to its detection. Using the apparatus still on view at the Deutsches Museum in Munich, he found that sparks across a gap in a rectangular wire frame could produce sparks in a similar but unconnected circuit. The distance between the transmitting and receiving circuits was gradually increased from 1.5

metres to right across the room.

After this initial discovery, Hertz went on to demonstrate that the radiation could be reflected and refracted like all other waves.

His patient investigations also found that illumination somehow facilitated sparking across a gap in a secondary coil. After carefully adjusting the gap so that no spark was seen in the dark, the spark came back when the lights were on. This was the first evidence for the photoelectric effect – the production of ions by light.

To commemorate Hertz' historic advances, the University of Karlsruhe is organizing a series of lectures culminating in a centenary ceremony on 5 December. A special exhibition will be held early next year. Other Hertz events have

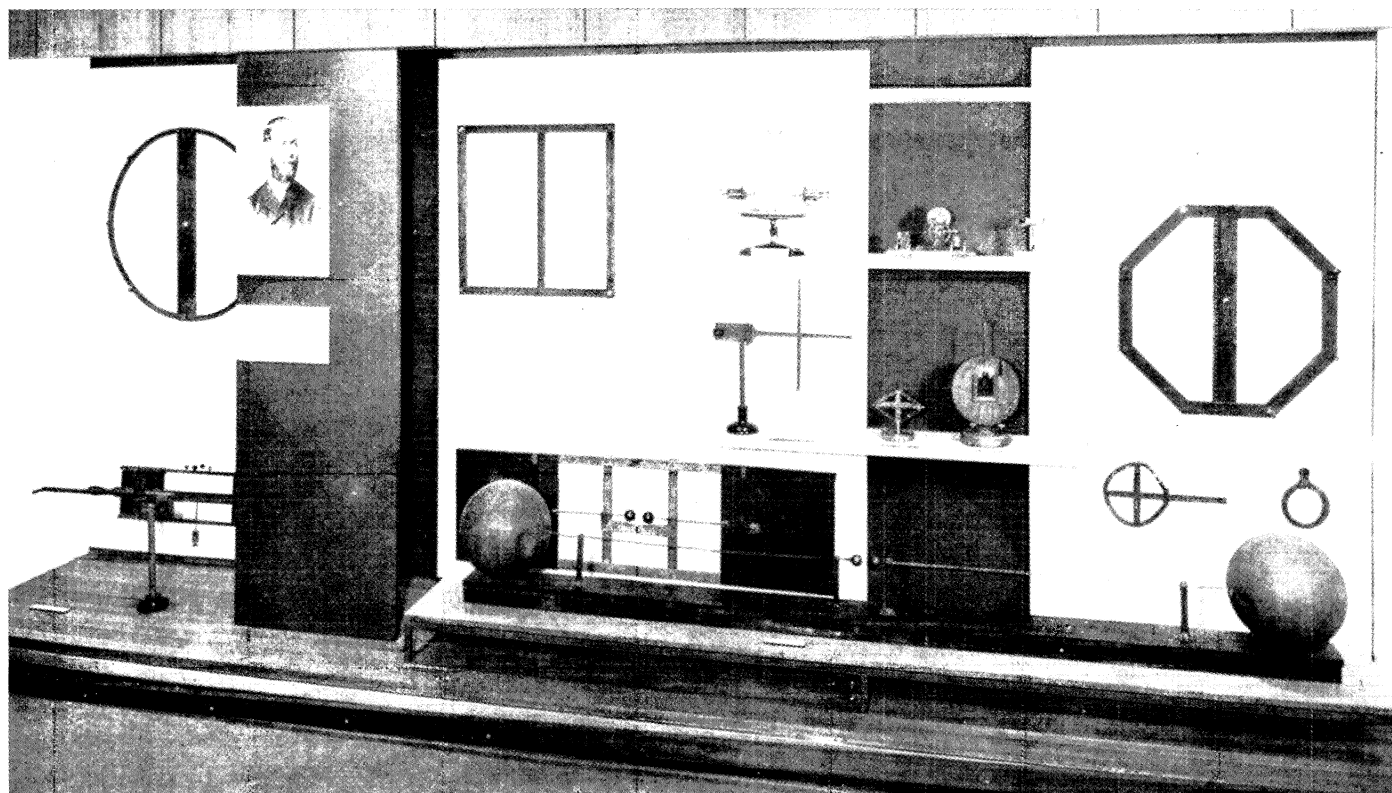
been organized in Hamburg, his birthplace, and at the Hertz Institute in Berlin.

G. F.

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*The apparatus used by Heinrich Hertz at Karlsruhe in 1887 to discover electromagnetic waves.*

*(Photo Deutsches Museum)*



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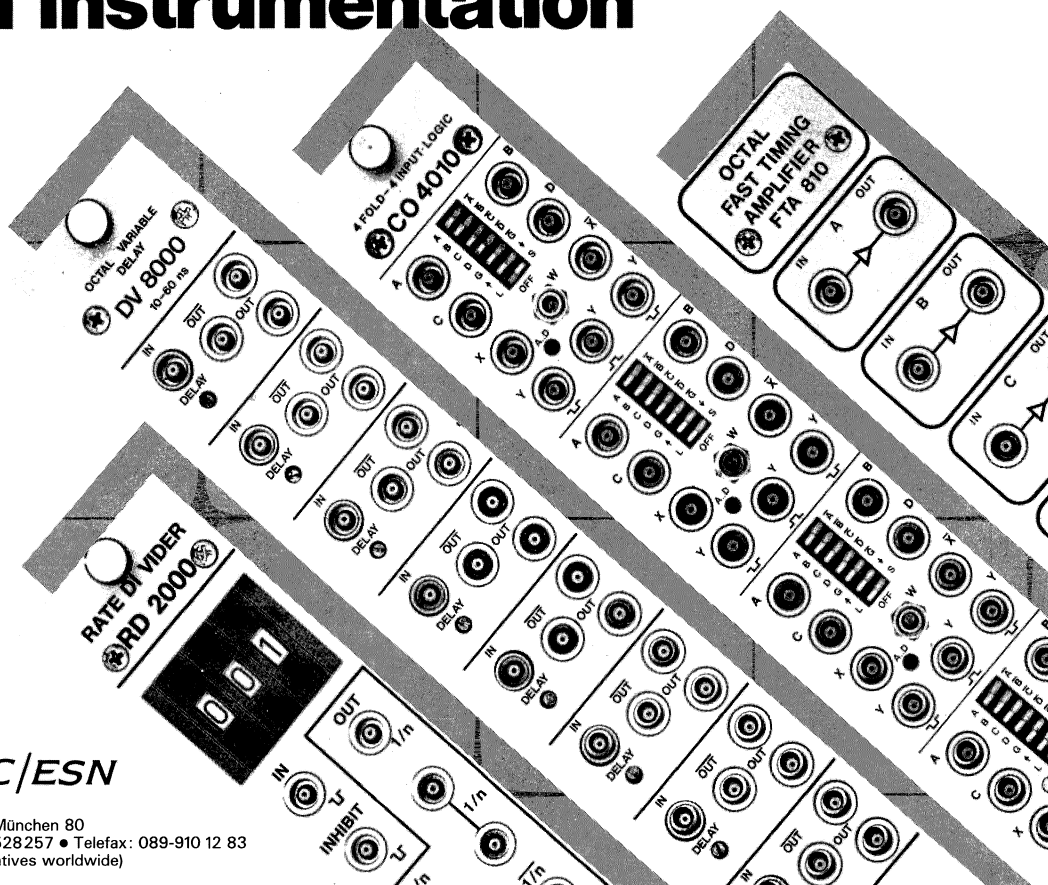
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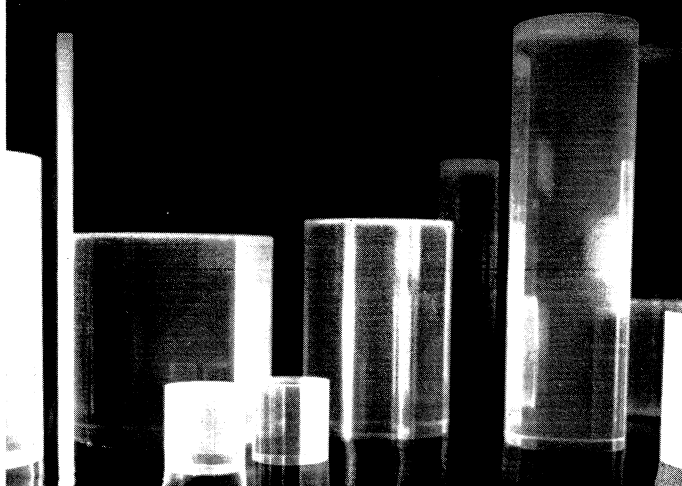
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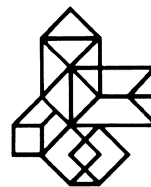
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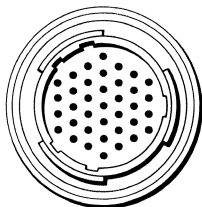
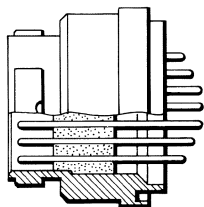
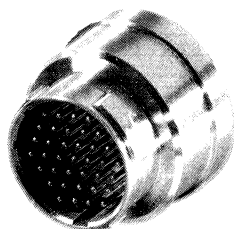
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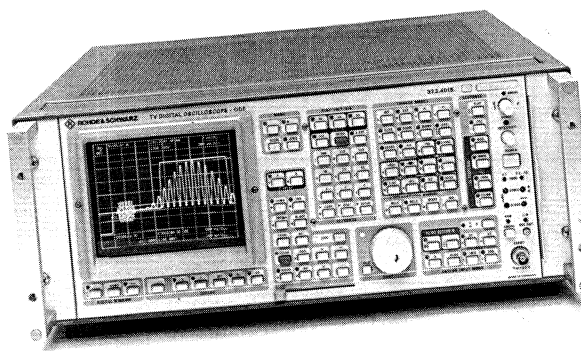
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