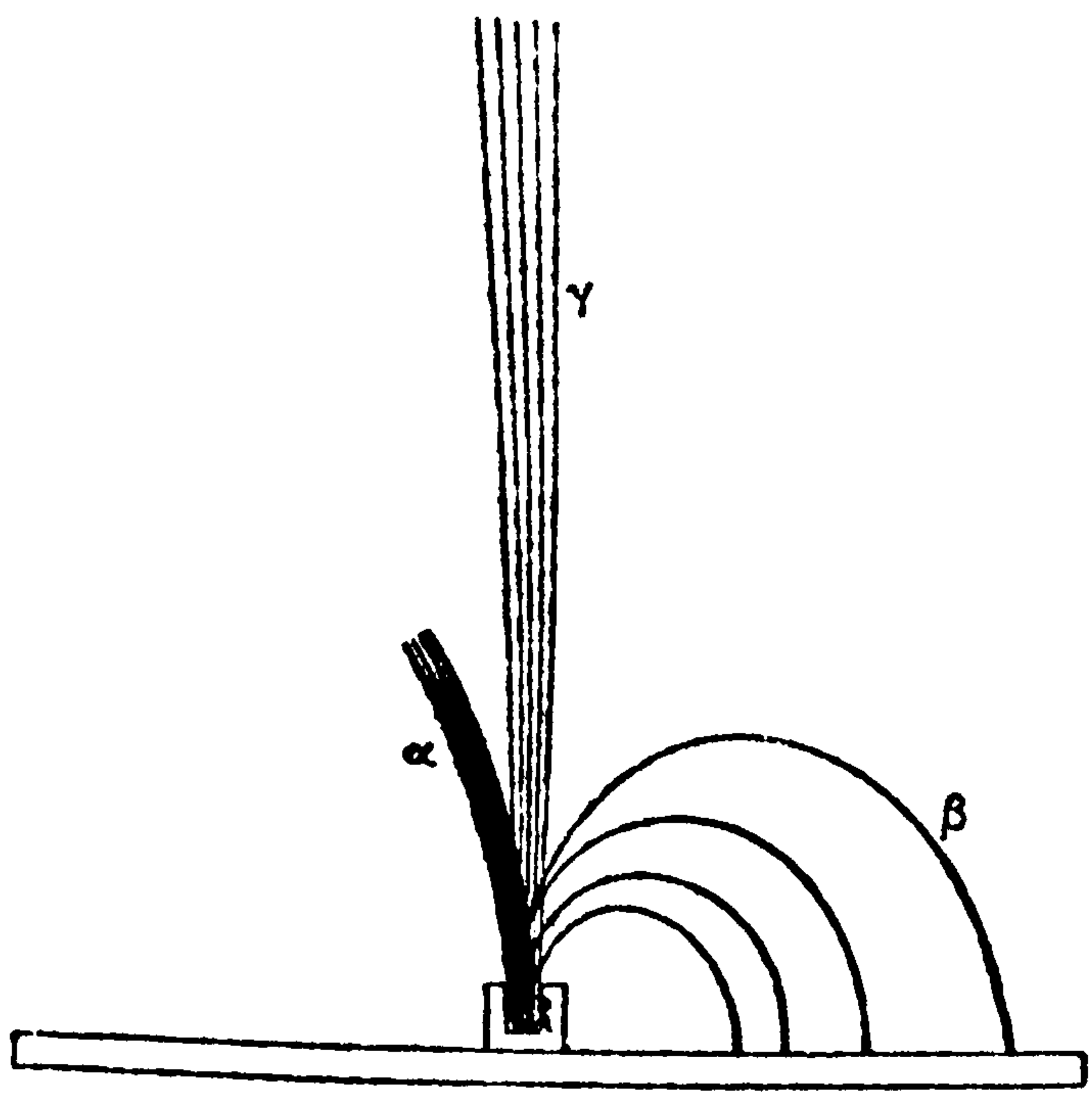
4

Some Landmarks in Modern Science



This catalogue has been especially printed for the winter dinner meeting of the CITIZENS ADVISORY COMMITTEE at The New York Public Library on February 10, 1954

SPEAKERS

HENRY BRUÈRE

Chairman of the Citizens Advisory Committee

MORRIS HADLEY

President of the Board of Trustees

DEVEREUX C. JOSEPHS

Trustee of The New York Public Library

REGINALD R. HAWKINS

Chief, Science and Technology Division

DR. J. ROBERT OPPENHEIMER

Guest of Honor

Some Landmarks in Modern Science

MODERN SCIENCE is too complex, too much the sum of the contributions of many men to be adequately represented by an armful of books. Nevertheless, there are landmarks, books and papers which stand above the common landscape. A few such writings have been selected for exhibition on this occasion.

When the earliest book shown was published in 1543, it was a revolutionary, but fortunately for the cause of science, an essentially accurate description of the mechanics of the solar system. The latest writing on display is a letter written in February 1939 by an eminent contemporary scientist to announce that man had indeed succeeded in releasing the energy of the atom.

In the four centuries encompassed, science has won respectability as a field of man's endeavor, it has progressed from the scrutiny of things visible to the naked eye to the study of the nucleus of the atom, and its findings have found wide application in the prolonging and betterment of man's life. Yet the year 1939 is recognized as the opening of a new scientific era, more portentous than any which has gone before.

REGINALD R. HAWKINS

1543 NICOLAUS COPERNICUS. *De revolvtionibvs orbivm cœlestivm.* Nuremburg, 1543.

The first edition of the foundation book of modern astronomy. In it Copernicus expounded the helio-centric theory of the universe. Its publication led to the gradual abandonment of the earlier theory that the sun and stars revolved around the earth as a center.

1543 ANDREAS VESALIUS. *De hvmani corporis fabrica.* Basel, 1555.

The foundation book of modern anatomy. In writing it the author broke away from the tradition of conforming to the writings of classical authorities and based his work on actual dissections and direct observations. The edition shown is the second. The first edition, published in 1543, is not owned by the Library.

1556 GEORG AGRICOLA. *De re metallica.* Basel, 1556.

The most accurate and fully detailed account of a sixteenth-century industry. Chiefly a description of the mining and metallurgical techniques of the author's own time, it contains also a theory of the origin of ore deposits, which still has some validity. The copy shown is one of the first edition. A translation made by Herbert Clark Hoover and his wife was published in 1912 and has itself achieved a degree of rarity.

1600 WILLIAM GILBERT. . . . *De magnete.* London, 1600.

Gilbert was an eminent London physician during the reign of Queen Elizabeth and was appointed royal physician in 1601. His principal claim to fame, however, derives from his scientific work, of which this book is the chief monument. It was based on a study of lodestones and other magnetized objects carried out by scientific experimentation over many years. In it the view that the earth itself is a huge magnet was first advanced.

1628 William Harvey. *Exercitatio anatomica de motu cordis et sanguinis.* Frankfurt, 1628.

The book in which the circulation of the blood was first accurately described. It was based both on a critical reading of previous writings on the topic and experimental investigation and thus was produced in the true spirit of modern science. The copy shown is a first edition.

1632 Galileo Galilei. *Dialogo de Galileo Galilei Linceo matematico sopraordinario dello studio di Pisa.* Florence, 1632.

Galileo's *Dialogue* has been called the Magna Charta of modern science because of its advocacy of observation and experience rather than dogma as the basis of science. In addition to presenting an ingenious defense of the Copernican system, it also conveys a detailed picture of the scientific atmosphere of Galileo's time. A copy of the first edition is displayed.

1665 Robert Hooke. *Micrographia.* London, 1665.

A first edition of a book famous for its beautiful and accurate illustrations of microscopic nature. It is also the book in which the fundamental units of living organisms were first described as cells.

1687 Sir Isaac Newton. *Philosophiæ naturalis principia mathematica.* London, 1687.

The great work of the great Newton whose position in English science is comparable to that of Shakespeare in English literature. The copy displayed is a first edition.

1827–38 JOHN JAMES AUDUBON. *The birds of America.* London, 1827–38.

Audubon set himself the task of portraying in life size and in faithful colors the birds of the New World. He worked from actual specimens and took pains to show natural poses. The plates were colored by hand. On display is a volume of the first edition as it was issued in London.

1832 MICHAEL FARADAY. *Experimental researches in electricity—Evolution of electricity from magnetism.* In: Royal Society of London, *Philosophical Transactions,* 1832.

In this paper, the discovery of the production of electric currents by induction was first announced to the world. This is the discovery about which a politician is said to have asked, "What good is it?" and to have drawn the reply from Faraday, "Within a few years, you can tax it." The remark is perhaps apocryphal, but the discovery has paid many millions in taxes, for it is the scientific principle on which most of the world's electric machinery and electric power systems are based. Ironically the same discovery was made independently by Joseph Henry, an American, a few months before Faraday, but the latter is given credit for it because he was the first to publish it.

1873 JAMES CLERK MAXWELL. *A treatise on electricity and magnetism.* Volume 1. Oxford, 1873.

James Clerk Maxwell, British physicist, lived from 1831 to 1879 and made several contributions of major significance to the development of physics. In this treatise he described electricity in terms of mathematics, developed the electromagnetic theory of light, and predicted electromagnetic waves in the part of the radiation spectrum now used for radio, television and radar. The book was the culmination of the classical period of physics.

1887 HEINRICH HERTZ. *Electric waves.* London, 1893.

Maxwell's prediction of electromagnetic waves attracted the attention of Heinrich Hertz, who began to look for them experimentally in 1886 and discovered them almost at once. The book shown is the first English edition of his writings on the subject. It is open to a passage in a paper which was first published in German in *Wiedemann's Annalen* in 1887. The small illustration shows a diagram of what was in principle, at least, the world's first radio system, although its value for communication was not recognized until Marconi began his work in 1895. The broadcasting range of Hertz' apparatus was about ten feet.

1895 WILHELM RÖNTGEN. *Eine neue art von Strahlen.* Würzburg, 1896.

Crookes' tubes were developed in the 1880s by Sir William Crookes as a means of studying electrical discharges through gases at low pressure. They were a laboratory tool primarily until Dr. Wilhelm Roentgen discovered that they emitted invisible radiation which had the power of passing through opaque substances. Roentgen called the rays he had discovered "X-radiation." This was soon shortened to "X-rays" and years later this radiation was named "Roentgen rays" in honor of their discoverer. Interestingly, Crookes quickly modified his tube so as to make it an efficient producer of X-rays and Crookes' X-ray tubes were soon in use throughout the world. The pamphlet shown is a reprint of the original paper.

1896 HENRI BECQUEREL. *Sur les radiations émises par phosphorescence.* In: Institut de France, Académie des Sciences, *Comptes Rendus*, February 24, 1896.

The discovery of Roentgen rays led Henri Becquerel to an investigation of the radiation emitted by naturally radioactive substances. These penetrating radiations had been observed before but it had been thought that they occurred only after the material had been exposed to daylight. Becquerel's discovery that activation by sunlight was not necessary was accidental but it opened up a vast new area of nature's secrets, which is still being intensively explored. Shown here is the first announcement of Becquerel's discovery. Below are reproductions of the first photographs made by natural radioactivity.

1899 ERNEST RUTHERFORD. *Uranium radiation and the electrical conduction produced by it.* In: *Philosophical Magazine and Journal of Science*, January, 1899.

Rutherford's significant studies of the newly discovered radiation followed quickly upon the publication of Becquerel's first reports. In this long paper Rutherford described experiments which established that two types of rays, which he named alpha and beta, were present. He missed the powerful gamma rays, which were found by a French scientist, P. Villard, in 1900.

1900 MAX PLANCK. *Ueber die Elementarquanta der Materie und der Elektricität.* In: *Annalen der Physik*, Band 4, January, 1901.

Discovery of X-rays and the invisible but powerful radiations of radioactive materials focussed the attention of physicists anew on the question of whether radiation consists of waves or discrete units of energy. Max Planck attacked the problem from the viewpoint of a theoretical physicist and in this paper introduced the important concept of a quantum of energy.

1904 MARIE CURIE. *Recherches sur les substances radioactives.* Deuxième édition. Paris, 1904.

Madame Curie suggested in 1899 the term "radioactive" to describe substances such as uranium which produce radiations, and she was the first to isolate radium. Shown here is the second edition of her famous doctoral dissertation.

1905 ALBERT EINSTEIN. *Ist die Trägheit eines Körpers von seinem Energieinhalt abhängig.* In: *Annalen des Physik,* Band 18, November, 1905.

Albert Einstein used mathematics rather than laboratory experimentation in tackling certain problems for which classical physics had failed to find satisfactory solutions. These include the problem of how radioactive substances could give out energy without being consumed. In this paper Einstein first stated clearly that energy and matter are different forms of the same thing and suggested further that the hypothesis could be proved by a study of the radioactive substances.

1906 LEE DE FOREST. *Device for amplifying feeble electrical currents.* United States Patent 841,387.

The basic patent on the three-element vacuum tube, sometimes described as the most valuable patent ever issued. It is related to an invention patented by Thomas A. Edison on October 21, 1884. In 1884 the electron had not been identified, the so-called

"Edison effect" exhibited by Edison's tube was not understood, and the invention found no commercial application. De Forest added the grid, the essential third element which controlled the flow of electrons, and the vast electronics industry developed from his invention.

1910 ROBERT ANDREWS MILLIKAN. *The isolation of an ion, a precision measurement of its charge, and the correction of Stokes's law.* In: *Science*, September 30, 1910.

Among his other scientific activities, Dr. Millikan carried out a series of experiments which were directed toward measuring the electron in terms of its electrical charge. This is his second published paper on this topic and the first in which he described a new experimental method which led a few years later to a very precise measurement and to proof that the electron is one of nature's fundamental units. The method, remarkable for its ingenuity and simplicity, is now known to students of physics as "Millikan's oil-drop experiment." In 1923, the Nobel prize in physics was awarded to Dr. Millikan.

1921 ALBERT EINSTEIN. *The meaning of relativity.* Princeton, 1923.

Four lectures delivered in English in May 1921 at Princeton University were published in this book. In the second lecture Einstein stated his now famous equation $E_0 = mc^2$ and again stated, "Mass and energy are therefore essentially alike; they are only different expressions for the same thing. The mass of a body is not a constant; it varies with changes in its energy."

1923 VLADIMIR K. ZWORYKIN. *Television system.* United States Patent 2,141,059.

Television like radio is based on the "Edison effect," but a practical television system was not evolved until Zworykin invented the highly specialized form of vacuum tube first described in the application for this patent. This invention made obsolete all of the television systems based on mechanical scanning on which countless inventors had labored for many years. It is interesting that fifteen years elapsed between the filing of the application and the issuing of the patent.

1932 JAMES CHADWICK. *The existence of a neutron.* In: Royal Society of London, *Proceedings,* June 1, 1932.

Experimental proof of the neutron was first reported in this paper. Its existence had been hypothesized years before, but positive evidence of its existence had not been produced theretofore. Only two years later Fermi and his co-workers used neutrons to penetrate the uranium nucleus.

1934 ENRICO FERMI, EDOARDO AMALDI, BRUNO PONTECORVO, FRANCO RASETTI, and EMILIO SEGRÉ. *Process for the production of radioactive substances.* United States Patent 2,206,634.

The basic patent on atomic energy. It covers the use of slow neutrons to penetrate the atomic nucleus. It is interesting that the inventors missed the energy angle completely and viewed their discovery as chiefly applicable to the production of radioactive isotopes. In 1953, the United States Government paid $300,000 for the use of this invention in the atomic energy program. Three of the inventors are now residents of the United States and one, Enrico Fermi, played a major role in the development of the atomic bomb.

1939 OTTO HAHN and FRITZ STRASSMANN. *Über den Nachweis und das Verhatten der bei der Bestrahlung des Urans mittels Neutronen ents-*

tebenden Erdalkalimetalle. In: *Die Naturwissenschaften*, January 6, 1939.

Although Fermi and his co-workers had developed by 1934 a practical technique for splitting uranium, and a German chemist, Frau I. Noddack, in an article published in 1934 criticizing Fermi's conclusions on his experiments with uranium, had pointed out that nuclear fission had almost certainly occurred, the fact was not plain to the world's physicists until the publication of this paper by Hahn and Strassmann. Even then, these authors would not commit themselves but only pointed out that it appeared that barium had been formed from uranium, although they themselves could not believe it.

1939 NEILS BOHR. *Resonance in uranium and thorium disintegrations and the phenomenon of nuclear fission.* In: *The Physical Review*, February 15, 1939.

Working in Professor Bohr's laboratory at the time of publication of Hahn and Strassmann's article were two refugees from Nazi Germany, Professor Lise Meitner and Dr. Otto Frisch. They interpreted correctly the results of Hahn and Strassmann's experiments and communicated the facts to Professor Bohr just before his departure to the United States to attend a meeting of physicists in Washington, D.C. Bohr's verbal communication of the news to American scientists resulted in feverish efforts to produce nuclear fission. This issue of *Physical Review* is famous because it contains reports of the verification of nuclear fission in four United States laboratories, including Bohr's letter from the Institute of Advanced Studies.