Foucault, Jean Bernard Léon

Complete Dictionary of Scientific Biography

(*b*. Paris, France, 19 September 1819; *d*. Paris, II February 1868)

experimental physics.

The son of a bookseller-publisher, Foucault received his education at home because of his delicate health. An indifferent student, he passed the *baccalauréat* only after special coaching and began to study medicine, hoping to put to use as a surgeon the considerable dexterity he had demonstrated (from the age of thirteen) in making a number of scientific toys, including a steam engine. Revolted by the sight of blood and suffering and stimulated in new directions by the invention of daguerreotypy, Foucault abandoned his medical studies, although not before he had come to the attention of Alfred Donné, teacher of clinical microscopy at the École de Médecine. Donné made him assistant in the microscopy course, then coauthor of its textbook (published in 1844- 1845). Foucault finally succeeded his master as science reporter for the newspaper *Journal des débats* (1845), thereafter writing, in a brilliant style at once lively and precise, a regular column in which he discussed for a general audience the latest from the world of science.

From 1844 to 1846 Foucault published geometry, arithmetic, and chemistry texts for the *baccalauréat*. Thereafter, except for his newspaper articles, he published only scientific papers. Foucault worked in a laboratory set up in his home until, following the award of the Cross of the Legion of Honor in 1851 (for his pendulum experiment) and the *docteur ès sciences physiques* in 1853 (for his thesis comparing the velocity of light in air and water), he was given a place as physicist at the Paris observatory by Napoleon III. Further honors followed: the Copley Medal of the Royal Society in 1855, officer of the Legion of Honor and member of the Bureau des Longitudes in 1862, and foreign member of the Royal Society (1864) and the academies of Berlin and St. Petersburg. Finally, after having failed to be elected in 1857, Foucault was chosen in 1865, following the death of Clapeyron, a member of the Académie des Sciences.

A nonobserving Catholic until his final illness returned him to the church, Foucault led a quiet life of total devotion to scientific research. Small and frail, he managed to preside gracefully over the group of scientific friends who gathered on Thursdays at his house in the rue d'Assas. He died of brain disease at the age of forty-eight after a seven-month illness.

Foucault is best-known for two of the most significant experiments of the mid-nineteenth century-the laboratory determination of the velocity of light (1850, 1862) and the mechanical demonstration of the earth's rotation (1851, 1852)-and for his advancement of the technology of the telescope. He also performed a number of other important experiments, chiefly in optics, and developed several devices which were widely used in both experimental science and technology.

In 1834 Charles Wheatstone developed a rotaingmirror apparatus to measure the velocity of electricity, and in 1838 Arago suggested that the same principle might be applied to determining the velocity of light terrestrially (earlier determinations were astronomical). A comparison of this velocity in air and in water would be a clear experimental test between the wave and particle theories of light, since the former required light to travel faster in air; the latter, in water. Arago's attempts to carry out the experiment were unsuccessful, and failing eyesight forced him to abandon them. Immediately Foucault and Hippolyte Fizeau, with whom Foucault had collaborated on optical researches between 1845 and 1847, began independently to attempt to overcome the obstacles that had defeated Arago.

Fizeau was the first to succeed; by replacing the rotating-mirror apparatus in the laboratory with a toothed wheel interrupting a ray of light traveling over a long terrestrial path, he obtained the first precision measurement of the velocity of light at the earth's surface in 1849. Fizeau returned to the rotating mirror to compare light's velocity in rare and dense media, but here he was beaten by Foucault, who announced on 30 April 1850 that "light travels faster in air than in water" (*Recueil*, p. 207). His apparatus is diagrammed in Figure 1. A source of light at *a* is reflected by a mirror *m*, rotating at 800 revolutions per second, to a spherically concave stationary mirror *M* and back again to *a′*. (The glass plane *g* permits the observer at *O* to see both source and reflection.) By the use of both an air path (upper half of diagram, image a′) and a water path (lower half of diagram,

water-filled tube *T*, image *a″*), the velocity of light, which is a function of the displacement of the reflected image *a′* or *a″* from the source image *a*, can be compared in the two media. Since the water image *a″* is deflected more than the air image, light must travel faster in air than in water.

Foucault's first experiment, carried out in 1850 and written up in full in his doctoral thesis of 1853, was purely comparative; he announced no numerical values until 1862. Then, with an improved apparatus, he was able to measure precisely the velocity of light in air. This result, significantly smaller than Fizeau's of 1849, changed the accepted value of solar parallax and vindicated the higher value which Le Verrier had calculated from astronomical data. Foucault's turning-mirror apparatus was the basis for the later determinations of the velocity of light by A. A. Michelson and Simon Newcomb.

With Fizeau, Foucault had pioneered in astronomical photography by making the first daguerreotype of the sun in 1845. The long exposures necessary for photographing the stars required that the telescope remain continuously pointed at the heavenly object. To regulate the drive for such a telescope, Foucault in 1847 brought into practice Christian Huygens' abortive seventeenth-century project for a clock with a conical pendulum. Foucault's clock had a steel rod to support the bob of its pendulum, and he noticed that such a rod, set vibrating while clamped in the chuck of a lathe, tended to maintain its plane of vibration when the lathe was rotated by hand.

This unexpected behavior of the rod suggested to Foucault an experimental demonstration of the earth's rotation. In the cellar of his house he mounted a pendulum with a five-kilogram bob suspended from a steel thread two meters long, free to swing in any direction and tied at the extremity of its swing with a thread. When the thread was set afire, the pendulum began swinging, and at 2 A.M. on Wednesday, 8 January 1851, Foucault was rewarded by the sight of the plane of swing of the pendulum gradually turning "in the direction of the diurnal movement of the celestial sphere" (*Recueil*, p. 378, n.). Repeating the experiment in the meridian hall of the Paris observatory with an eleven-meter-long pendulum, Foucault reported to the Académie des Sciences on 3 February 1851 his finding that the circle described by the plane of the pendulum's swing is inversely proportional to the sine of the latitude. This experiment, soon scaled up and moved to the Panthéon, was repeated during the next two years in a number of places all over the world and gave rise to a tenfold increase in the scientific papers devoted to the pendulum.

As Foucault claimed in his report to the Academy, his finding illustrated Poisson's theoretical treatment of the deflecting force of the earth's rotation (*Journal de l'École polytechnique*, **16** [1838], (1-68), but Poisson had explicitly denied that the effect on the pendulum could be observed (p. 24).

Continuing to experiment on the mechanics of the earth's rotation, Foucault in 1852 invented the gyroscope, which, he showed, gave a clearer demonstration than the pendulum of the earth's rotation and had the property, similar to that of the magnetic needle, of maintaining a fixed direction. Foucault's pendulum and gyroscope had more than a popular significance (which continues to this day). First, they stimulated the development of theoretical mechanics, making relative motion and the theories of the pendulum and the gyroscope standard topics for study and investigation. Second, prior to Foucault's demonstrations the study of those motions on the earth's surface in which the deflecting force of rotation plays a prominent part (especially winds and ocean currents) was dominated by unphysical notions of how this force acted. Foucault's demonstrations and the theoretical treatments they inspired showed conclusively that this deflecting force acts in all horizontal directions, thus providing the sound physical insight on which Buys Ballot, Ferrel, Ulrich Vettin, and others could build.

Their daguerreotype of the sun was only one fruit of the collaboration between Foucault and Fizeau. Together, between 1844 and 1847, they carried out half a dozen researches. Two were of special importance: in 1845 and 1846 they extended the experiments of Thomas Young and Fresnel to show that interference took place between rays of light of which the paths differed by several thousand wavelengths, and in 1847 they showed, by studying the interference of heat rays from the sun, that radiant heat has a wavelike structure identical with that of light. These two experiments considerably strengthened the wave theory of light.

With his close friend Jules Regnault, Foucault showed in 1848 how the brain combines into one image two separate colors, each presented to a single eye. Shortly thereafter Foucault threw sunlight on the light from a carbon arc to superimpose the spectra. From his observation that the double bright-yellow line of the arc was identical with the double dark line in the solar spectrum (D line from sodium), he concluded that the arc could absorb the same light that it emitted, but the generalization of this observation to explain the Fraunhofer lines was left for Kirchhoff in 1859.

In 1853 Foucault studied conductivity in liquids, and in 1855 he demonstrated the conversion of mechanical work into heat by turning with a crank a copper disk placed between the poles of an electromagnet and measuring the heat produced in the disk.

No one in his time exceeded Foucault in technical inventiveness. From his first published papers on improvements in daguerreotypy (1841, 1843) to the completion of his siderostat shortly after his death, the devices designed by Foucault and executed, first by himself and later with the help of others, solved outstanding problems of practice in both science and technology. He developed a regulator for the arc lamp, which made it possible for gas to be supplanted by electricity in the supply of artificial light to the microscope (1843), and his improvement to this regulator (1849) brought the arc lamp into the theater. He designed a photometer (1855). His mercury interrupter (1856) improved the performance of Ruhmkorff induction coils, and his birefringent prism (1857), using air rather than balsam between the two pieces, made it possible to obtain plane polarized light into the ultraviolet. About 1860 he returned to the problem of making mechanical motion uniform, which had led him to the pendulum experiment, and he developed a whole series of mechanical regulators which went considerably beyond James Watt's governor in their effectiveness. These regulators were used first in machines which kept a telescope pointed continuously at the sun (heliostat) or a star (siderostat) and then in large steam engines, both in factories and at the Paris Exposition of 1867.

None of these inventions, however, was as significant for science as Foucault's introduction of the modern technique for silvering glass to make mirrors for reflecting telescopes (1857) and his simple but accurate methods for testing and correcting the figure of both mirrors and lenses (1858). Glass proved much superior to the speculum metal previously used in reflecting telescopes because it is much lighter in weight, easier to grind and figure, and easier to resurface if it becomes tarnished or damaged.

Foucault's extraordinary command of a precise language in both word and deed was not always taken at its true worth by his contemporaries among the masters of the French analytic tradition, for whom his sparing use of mathematics condemned him as merely a lucky tinkerer. His pungent newspaper articles, although never vicious, were also a source of hostility. Foucault's interest in astrophysics met the firm opposition of Le Verrier, director of the Paris observatory, a theoretical astronomer of the old school, and Foucault was therefore prevented from installing his siderostat in the observatory. Nevertheless, before he died, Foucault had acquired the respect of all as an outstanding experimentalist; and his reputation grew after his death as modern telescopic astronomy developed on the basis of the optical techniques he had inaugurated.

BIBLIOGRAPHY

I. Original Works. Foucault's papers, published mostly in the *Comptes rendus hebdomadaires des séances de l'Académie des sciences*, were collected and issued together with a number of unpublished papers in *Recueil des travaux scientifiques de Léon Foucault*, 2 vols. in one (Paris, 1878). Figure 1 in the text is taken from Plate 4 of the *Recueil*, which is in turn taken from Foucault's thesis, *Sur les vitesses relatives de la lumiére dans l'air et dans l'eau* (Paris, 1853).

II. Secondary Literature. The two chief sources for Foucault's life and work are also in the *Recueil*: J. Bertrand, "Avertissement", I, i-iv, and "Des progrés de la mécanique," I, v-xxviii, the latter originally published in *Revue des deux mondes*, **51** (1 May 1864), 96-115, in order to help Foucault's candidacy for the Académie des Sciences; and J. A. Lissajous, "Notice historique sur la vie et les travaux de Léon Foucault," II, 1-18. Also useful is P. Gilbert, "Leon Foucault, sa vie et son oeuvre scientifique," in *Revue des questions scientifiques*, **5** (1879), 108-154, 516-563. Betrand alludes in his article to the opposition Foucault faced in the Academy; the opposition of Le Verrier is mentioned in P. Larousse, *Grand dictionnaire universel du XIXe siècle*, VIII (Paris, 1872), 649.

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