Fizeau, Armand-Hippolyte-Louis | Encyclopedia.com

(*b*. Paris France, 23 September 1819; *d*. Venteuil, near Jouarre, France, 18 September 1896)

experimental physics.

Fizeau was the eldest son of a large and relatively wealthy family that had come to Paris from the Vendeé. His father held the chair of internal pathology at the Paris Faculty of Medicine from 1823. Fizeau, aspiring to follow in his father's footsteps, began medical studies at the Collegè Stanislas, but because of poor health he was obliged to interrupt his education in order to travel to a more agreeable climate. On returning to Paris, he gave up medicine and began an entirely new career in the physical sciences. At the Collége de France, he studied optics with H.-V. Regnault, and he followed the lectures given at the École Polytechnique through the notebooks compiled by one of his brothers. Fizeau's most fruitful educational experience, however, was the course of study he took at the Paris observatory under the tutelage of the famous astronomer François Arago. Arago recognized Fizeau's promise, encouraged his scientific endeavors, and brought his work to the attention of the Academy of Sciences.

Fizeau was made a member of the section of physics of the Academy of Sciences on 2 January 1860. He was vice-president of his section for 1877 and president for 1878. In 1878 he was elected to the Bureau of Longitudes. On 9 July 1856 the five academies constituting the Institut de France awarded him the Triennial Prize, a special award that had just been created by the emperor. From the Royal Society he received the Rumford Medal in 1866 and the title of foreign member in 1875.

On 19 August 1839 Arago made public a description of a new process of "light painting" or heliography that had been invented by L.-J.-M. Daguerre. The daguerrotype, as the result of this process soon came to be called, was a crude forerunner of the modern photograph. Fitzeau's earliest work in science was an attempt to improve Daguerre's process and to make the heliograph an instrument of science. He showed that by covering the surface of the developed plate with a salt of gold, oxidation of the surface chemicals could be prevented and the contrasts between light and dark could be considerably heightened. He is often credited with the first use of bromine vapors to hasten the development of the photographic image, but this seems uncertain.[1] Fizeau also introduced a widely used but unpatented method for turning a photograph into a photoetching.

During this early period of his career, Fizeau often worked in collabroation with Léon Foucault, a young man who had also begun his education in medicine. Foucault was one of the most adept mechanicians of his age, and had he been able to tolerate the sight of blood, he might have become a great surgeon. Together the two young scientists worked on the improvement of photographic images, and in 1845 they opened a new and fruitful area of astronomy by taking what were probably the first clear photographs of the sun's surface [2].

From 1844 Fizeau and Foucault undertook a series of precise and mechanically ingenious optical experiments that would ultimately have a profound effect on the course of physics. By the middle of the nineteenth century, most scientists had come to accept the wave theory of light, formulated near the beginning of the century by Thomas Young and Augustin Fresnel. There remained, however, several gaps in the investigation of the experimental consequences of the theory. For example, in the study of interference fringes produced by two rays of light issuing from the same source, only several dozen fringes on each side of the central band had been observed.

By analyzing the white light source into simpler constituents by means of a spectroscope, Fizeau and Foucault were able to observe fringes produced by interfering light rays with a difference of travel equal to more than 7,000 wavelengths, thus showing that light waves, like sound waves, remain geometrically constant over a like sound waves, remain geometrically constant over a large number of periods. But light waves, because of their transverse vibrations, are more complex than sound waves. Light can assume different forms or planes of vibration as well as different intensities. Using the same spectroscopic apparatus as in the preceding experiment, Fizeau and Foucault observed the interaction of two rays produced by passing a single polarized ray through a birefringent crystal. In this case, instead of obtainig alternating bands of light and dark, they obtained bands of light periodically polarized in different planes of vibration.

In 1800 William Herschel, the British astronomer, discovered a form of invisible radiation above the red end of the spectrum which produced a heating effect. The infrared rays (or calorific rays as they were usually called) were shown to follow most laws that had been established for visible light. By using extremely small and delicate thermometers, Fizeau and Foucault demonstrated that calorific rays could produce interference fringes like those produced by visible light, except that instead of appearing as alternating bands of light and dark, the fringes produced by infrared rays appeared as alternating bands of hot and cold.

One of the most important consequences of the wave theory of light that had not yet been demonstrated was that light traveled more slowly in dense than in rare mediums. In 1838 Arago had suggested using a rapidly rotating mirror for the purpose of this demonstration, a technique employed by Charles Wheatstone in 1834 in an unsuccessful attempt to measure the speed of electricity. In principle, Arago's idea was very simple. A narrow ray of light would be directed into a mirror rotating as rapidly as possible. The light from this mirror would be reflected back over the same path by a fixed mirror placed at a considerable distance. By the time the light had returned, the rotating mirror, having suffered a small angular displacement, would deflect the light off at an angle to the original path. If, in addition, the light returning from the fixed mirror were divided into two rays and one of them were sent through a tube of water, it would then be possible to establish directly, and without having to measure the absolute speeds of the two rays, whether the light had been slowed by its passage through the denser medium. Theoretically, the ray that had come through the tube filled with water would arrive at the rotating mirror a fraction of a second after the ray that had come through the air and would thus be deflected at a greater angle.

In practice, the essential problem was to arrange an optical system such that the narrow, intermittent rays of light were not dispersed in their passage between the two mirrors. After considerable trial, Fizeau and Foucault found a workable system, the essential element of which was a convergent reflector of convenient focal length. Unfortunately, once having solved this problem, the two experimenters broke up their partnership over a personal dispute. Each continued to work on the experiment. On 6 May 1850 two papers on the relative speeds of light in water and in air were submitted to the Academy of Sciences, one signed by Foucault, the other by Fizeau and Louis Bréguet. With almost identical apparatus, the two experiments had yielded substantially the same result. Light did, indeed, travel faster in air than in water.

Fizeau was not satisfied merely with determining the relative velocities of light. He wanted to measure with some precision the absolute velocity. In 1849 he had conceived an ingenious mechanism that would enable him to achieve his goal: a large toothed wheel was spun rapidly about its axis, and a beam of light sent through the spaces between the teeth was reflected back to its source by a fixed mirror. When the wheel was rotated rapidly enough, the intermittent light rays returning from the mirror intersected the path of the teeth and thus became invisible to the observer stationed behind the wheel. As the mechanism was turned faster and faster, the light reappeared and disappeared alternately. The time required for the light to travel through the carefully measured distance was a simple function of the angular displacement of the wheel.

In 1849 Fizeau made a trial of his new method between his father's house at Suresnes and Montmartre. The figure he obtained for the speed of light (about 315,000 kilometers per second) was not quite as accurate as the results of astronomical calculations, but the practicability of the method was established and became the basis of the more precise determinations made by Alfred Cornu in the 1870's.

By substituting for teeth alternating bands of conducting and nonconducting materials, Fizeau attempted with little success to adopt his mechanism to the measurement of the speed of electricity. (A galvanometer, of course, replaced the eye of the observer.) In 1849 Fizeau tried the experiment with the engineer E. Gounelle, but the results were indecisive because of the complex way in which electricity is propagated through a conductor.

In 1848 Fizeau published a paper that was to have a profound effect on the future of astrophysics. He showed that when a body emitting a continuous sound of unvarying frequency is moved, the sound waves do not dispose themselves symmetrically about the source. In front they come at shorter intervals, producing the effect of higher pitch; from behind the frequency appears lowered because of the larger interval between wave crests. (The sound of a passing railroad train is the classic example of this phenomenon.) Fizeau saw the implications of this principle for optics. A moving light source would undergo an analogous change in frequency. From behind, the light waves would be shifted toward the red end of the spectrum; from the front they would be shifted toward the violet.

Unknown to Fizeau, a physicist from Prague, Christian Doppler, had published a paper on exactly the same subject in 1842, six years before the appearance of Fizeau's work. Doppler, however, failed to understand correctly some of the consequences of his own idea. He supposed that light coming from a star moving relative to the earth would experience a change in color [3]. He was apparently unaware of the invisible radiations at the red and violet ends of the spectrum that would, by their shift into the visible range of the spectrum, compensate for the disappearance of any colored rays. The Doppler-Fizeau effect became useful in astronomy only after the work of Gustav Kirchhoff and Robert Bunsen showing that incandescent elements emit discrete frequencies of light. It then became possible, by measuring the shift in the spectra produced by the various elements in a given star, to ascertain the velocity of that star relative to the earth. The first such measurement was made in 1868 by the British astronomer William Huggins, and since then the technique has provided the science of astrophysics with one of its most important tools for measuring the size and structure of the universe.

Nearly all scientists in the nineteenth century believed that some sort of luminiferous ether filled the universe and provided the medium for the propagation of light. One of the many problems that arose with respect to the nature of the ether was whether it could participate in the motion of ponderous matter. In 1818 Fresnel discussed this question in a famous letter addressed to Arago. He assumed that bodies carried with them only as much ether as they contained in excess of that which was present in an equal volume of space void of all ponderous matter. By assuming in addition that the excess of ether contained in a given body of matter was proportional to its refractive index, Fresnel deduced that the percentage of a body's motion that could be communicated to light was equal to , where *n* represents the refractive index.

In 1851 Fizeau found a way of overcoming the seemingly impossible difficulty of measuring the small increment in the velocity of light that in theory would be produced by a body in motion. His method was simply to produce interference fringes from rays of light that had passed through two parallel tubes containing a fluid moving in opposite directions. Even a relatively small difference in the velocity of the two light rays would cause a perceptible displacement of the interference fringes. Using air as the test medium, Fizeau discerned no change in the speed of light, a result that he expected because the refractive index of air is equal almost to one. With water, however, the velocity of light was altered by an amount that accorded reasonably well with Fresnel's formula. In 1886 A. A. Michelson and E. W. Morley repeated the experiment on a larger scale and confirmed Fizeau's results.

In a world that was becoming increasingly professional, Fizeau was one of the last great amateurs of science. He was able to employ his personal wealth and virtually unlimited leisure in pursuit of his scientific researches. Except for the Doppler-Fizeau effect, he made no direct contributions to optical theory, but the ingenious experimental techniques that he invented were to supply an invaluable aid to the creation in this century of a new optics. That his reputation has not equaled his deeds is largely because once he had invented a new experimental method, he left it to his followers and collaborators to develop and perfect. Foucault went on to employ the rotating-mirror device in precise measurements of the speed of light; Cornu perfected the toothedwheel mechanism for the same purpose; and much of the career of A. A. Michelson was built on Fizeau's unfinished business.

Fizeau married a daughter of the famous botanist Adrien de Jussieu. She died early in the marriage, after having given birth to two daughters and a son. After his wife's death, Fizeau retired to his home near Jouarre and came to Paris only rarely, to attend meetings of the Academy of Sciences and the Bureau of Longitudes. He died of cancer of the jaw just five days before his seventy-seventh birthday. His son and younger daughter survived him.

NOTES

1. Historians of photography sometimes give credit for this development to the Englishman J. F. Goddard, but since the photosensitive properties of silver bromide were widely known, the idea of trying bromine vapors in place of iodine was, perhaps, too obvious to be considered an important discovery.

2. A photograph of the moon had been taken as early as 1840 by J. W. Draper of New York.

3. Stars do change color, but not in the way that Doppler thought they did. The intensities of stars' electromagnetic emissions are not equitably distributed throughout the spectrum, and any shift in the maximum energy distribution of a star's visible light will appear as a color change; what Doppler failed to understand was the idea of frequency shift.

BIBLIOGRAPHY

Fizeau wrote no major publications. A list of his scientific articles is in Émile Picard, *Les théories de l'optique et l'oeuvre d' Hipployte Fizeau* (Paris, 1924), pp. 57–64. There is also a list, presumably complete, in the Royal Society's *Catalogue of Scientific Papers*. Unfortunately there is no major biography of Fizeau. Virtually all the information we have about his life and work comes from Alfred Cornu, "Notice sur l'oeuvre scientifique d'Hippolyte Fizeau," in *Annuaire pour l'an 1898, publiè par le Bureau des longitudes* (Paris, 1898[?]), notice C, pp. 1–40. The work by Picard, mentioned above, contains substantially the same information, but Picard has attempted to place his discussion in a broader historical context by relating Fizeau's work to the optical theories that came before and after him. A number of brief biographical notices appeared in various scientific journals just after Fizeau's death. A list of them is found in Picard, p.64. The Academy of Sciences in Paris is reported to have some of Fizeau's MSS and a portrait.

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