Etienne Louis Malus | Encyclopedia.com

Complete Dictionary of Scientific Biography COPYRIGHT 2008 Charles Scribner's Sons
11-14 minutes

(*b*. Paris, France, 23 July 1775; *d*. Paris, 24 February 1812)

optics.

The son of Anne-Louis Malus du Mitry and Louise-Charlotte Desboves, Malus was privately educated, mainly in Greek, Latin, and mathematics. He revealed his mathematical skill in 1793 at the entrance examination to the military school in Mézières. His father's position as treasurer of France compromised the family during the Revolution; so Malus served as a simple soldier until 1794, when he was sent to the École Polytechnique. He became sublieutenant of engineers on 20 February 1796 and captain of engineers on 19 June 1796, and he took part in Napoleon's expedition to Egypt and Syria (1798–1801). Malus survived an infection and landed in Marseilles on 14 October 1801. In 1802–1803 he was at Lille; he was subdirector for the fortifications of Anvers (1804–1806) and Strasbourg (1806–1808). In 1808 Malus was called to Paris, where he became major of engineers on 5 December 1810.

Malus was among the first students to enter the École Polytechnique, where he received his basic scientific education (1794–1796). Interested primarily in optics, he composed a memoir in Cairo stating that the constituent principle of light was a particular combination of caloric and oxygen. In September 1802 the Société des Sciences, de l'Agriculture et des Arts de Lille began regular meetings; Malus became vicepresident on 11 February 1803 and president the following January. From 1805 he was examiner in geometry and analysis at the école Polytechnique and, from 1806, in physics as well. This post gave Malus the opportunity of long stays in Paris and contacts with other physicists. On 20 April 1807 he presented his first memoir, "Traité d'Optique," to the first class of the Institute. He received the mathematical prize of the Institute on 2 January 1810. The greatest event in Malus's career was undoubtedly his election to membership of the first class of the Institute (18 August 1810). Malus was also a member of the Institut d'Égypte (22 August 1798), the Société d'Arcueil (1809), and the Société Philomatique (April 1810). On 22 March 1811 Thomas Young informed Malus that the Royal Society of London had awarded him the Rumford Medal. His last memoir was read to the Institute on 19 August 1811.

At Giessen, just before he was ordered to Egypt, he planned to marry Wilhelmine-Louise Koch, the eldest daughter of the university chancellor, but they were not married until after his return. She died on 18 August 1813. Malus's influential friends included Monge, whom he first met as director of the École Polytechnique; Berthollet, who also was with Napoleon on the Egyptian expedition; and Laplace, who at the beginning of the nineteenth century was particularly interested in optics.

In "Traité d'optique" Malus considered mathematically the properties of a system of contiguous rays of light in three dimensions. He found the equation of the caustic surfaces, and the Malus theorem: Light rays emanating from a point source, after being reflected or refracted from a surface, are all normal to a common surface, but after a second reflection or refraction they will no longer have this property. If the perpendicular surface is identified with a wavefront, it is obvious that this result is false, which Malus did not realize because he adhered to the Newtonian emission theory of light, and the Malus theorem was not proved in its full generality until W. R. Hamilton (1824) and Quetelet and Gergonne (1825). The line of thought and the results of the results of the "Traité d'optique" were continued and generalized by Hamilton in his "Theory of Systems of Rays" (1827).

Double refraction had first been observed in Iceland spar by Erasmus Bartholin. The laws governing it were found by Huygens from the assumption that the wavelets of the extraordinary rays were ellipsoids of revolution with major axes parallel to the axis of the crystal. If one crystal of Iceland spar is placed over another in such a way that the principal sections of the crystals are parallel, then the ordinary rays produced in the upper crystal undergo ordinary refraction only in the lower crystal, while the extraordinary rays undergo only an extraordinary refraction. If the principal sections are perpendicular to each other, the ordinary rays undergo an extraordinary refraction and vice versa. Huygens could not account for these observations, and Newton used them to refute Huygens' wave theory. Newton considered light as particles, and the above-mentioned polarization phenomenon indicated to him that these particles had sides. In Query 25 of the *Optics* he announced his own (false) rule for double refraction, which was adopted for the next century. In 1788 Haüy found experimentally that Huygens' law was true only in certain special cases, but in 1802 Wollaston found experimental evidence for the Huygenian construction. In "Mémoire sur la mesure du pouvoir réfringent" Malus showed that Wollaston's experiments were incomplete, and so the French corpuscularian physicists did not trust Wollaston's results. They thought, moreover, that Wollaston was associated with Thomas Young and therefore with the wave hypothesis.

In this situation the Institute on 4 January 1808 proposed a prize which required an experimental and theoretical explanation of double refraction. The French "Newtonian" scientists hoped that Malus would find a precise and general law for double refraction within the framework of an emission theory of light. Malus was a skilled mathematician and during 1807 he had carried out experiments on double refraction. By December 1808 Malus had finished his experimental investigations, which verified the Huygenian law. What remained was a theoretical deduction of the law. In January 1809, Laplace published a memoir in which he deduced Huygens' law within the framework of Newtonian mechanics, using the principle of least action, and Malus considered this an insolence which deprived him of the priority. In 1810 Malus won the prize for his "Théorie de la double réfraction," published in 1811. Here he deduced the law following the same method as Laplace, by means of the principle of least action. Malus won the prize therefore mainly because of his original experimental researches and his discussion of the short-range forces that produce double refraction. Also of great importance was his law for the relative intensities of the ordinary and extraordinary rays.

While working on double refraction Malus discovered that a ray of sunlight reflected at a certain angle from a transparent medium behaves in exactly the same manner as if it had been ordinarily refracted by a double refracting medium. He found that each medium had a characteristic angle of reflection for which this happend, 52°45′ for water and 35°25′ for glass. Malus did not postpone publishing his discovery until the end of the competition, but announced it to the Institute on 12 December 1808. He also showed that if the two rays emanating from a crystal are reflected from a water surface at an angle less than 52°45' and if the principal section of the crystal is parallel to the plane of reflection then the ordinary ray is totally refracted; and if the principal section is perpendicular to the plane of reflection the extraordinary ray is totally refracted. He concluded that these phenomena could be accounted for only supposing that light consisted of particles which were lined up by reflection and refraction and remained mutually parallel afterward. In "Mémoire sur de nouveaux phé nomènes d'optique" Malus said that light particles have sides or poles and used for the first time the word "polarization" to characterize the phenomenon.

All transparent and opaque bodies polarize light more or less by reflection, and for each medium a characteristic angle of reflection will totally polarize the reflected ray in the plane of reflection. The refracted rays will contain light that is polarized perpendicular to the reflected light and light that is not polarized. Malus carried out numerous experiments to determine characteristic angles and relative intensities. If the intensity of the incident, polarized ray is unity, then the intensity I of ray reflected at the characteristic angle will be $I \equiv \cos^2 \alpha$, where α is the angle between the planes of polarization of the incident and the reflected rays. He also found the relative intensities of reflected and ordinarily and extraordinarily refracted light. For instance Malus found that if two double refracting crystals are placed one above the other with parallel refracting surfaces, the relative intensities I_{oo}, I_{oe}, I_{eo}, and I_{ee} of the rays subject to ordinary-ordinary, ordinary-extraordinary, extraordinary-ordinary, and extraordinary-extraordinary refraction will be

$$I_{oo} = I_{ee} = \cos^2 i$$

$$I_{oe} = I_{eo} = \sin^2 i,$$

where i is the angle between the two principal sections. He also found that the ordinary and extraordinary rays are polarized perpendicularly to each other.

All material bodies will, to a certain extent, polarize rays of light by reflection. At first Malus thought that this was not true of metallic surfaces, but he later found that rays reflected from such a surface contain two kinds of mutual perpendicularly polarized light together with light not polarized. By reflection at a certain angle, later called the principal angle of incidence, all the reflected light was circularly polarized (Malus did not use this term). The theory of metallic reflection was developed by Brewster, MacCullagh, and Cauchy.

Malus did not indicate whether his results were found experimentally or theoretically. After his death his researches on polarization were followed up by Arago and Biot in France and Brewster in England. In the wave theory of light polarization was explained from the assumption of the transversality of light waves. This was proposed both by Fresnel and Young (1816), but it was not until 1821 that Fresnel succeeded in laying a mechanical foundation for the theory of transverse waves in an elastic medium.

BIBLIOGRAPHY

I. Original Works. A bibliography of sixteen memoirs by Malus is in Royal Society *Catalogue of Scientific Papers*, IV, 210–211. Those cited in the text are "Mémoire sur la mesure du puovoir réfringent des corps opaques," in *Nouveau bulletin des sciences de la Société philomatique de Paris*, **1** (1807), 77–81; "Mémoire sur de nouveaux phénomènes d'optique," *ibid*., **2** (1811), 291–295; "Traité d'optique," in *Mémoires présentés à l'Institut des sciences par divers savants*, **2** (1811), 214–302; and "Théorie de la double réfraction de la lumière dans les substances cristallines," *ibid*., 303–508. Malus recorded his activities on scientific expeditions to various parts of Egypt in his diary, published posthumously as *L'agenda de Malus. Souvenirs de l'expédition d'Égypte 1798–1801* (Paris, 1892). Collections of MSS are at the Bibliothèque de l'Institut and the Archives de l'Académie des Sciences in Paris.

II. Secondary Literature. On his life, see the biographies by Jean-Baptiste Biot, in Michaud, ed., *Biographie universelle*, XXVI (Paris, 1820), 410 ff.; and by François Arago in his *Oeuvres*, III (Paris, 1855), 113–155. Much valuable information can be found in M. Crosland, *The Society of Arcueil* (London, 1967). See also Anatole de Norguet, "Malus, fondateur de la Société des sciences de Lille," in *Mémoires de las Société des science, de l'agriculture et des arts de Lille*, 3rd ser., **10** (1872), 225–

232. The history of the Malus theorem is presented in *The Mathematical Papers of Sir William Rowan Hamilton*, I (Cambridge, 1931), 463 ff. Laplace's paper on double refraction, "Mémoire sur les mouvements de la lumière dans les milieux diaphanes," is in *Oeuvres complète de Laplace*, XII (Paris, 1898), 267–298.

Kurt MØller Pedersen