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(*b*. Mulhouse, Alsace, 26 [?] August 1728; *d*. Berlin, Germany, 25 September 1777)

mathematics, physics, astronomy, philosophy.

The Lambert family had come to Mulhouse from Lorraine as Calvinist refugees in 1635. Lambert's father and grandfather were tailors. His father, Lukas Lambert, married Elisabeth Schmerber in 1724. At his death in 1747, he left his widow with five boys and two girls.

Growing up in impoverished circumstances, Johann Heinrich had to leave school at the age of twelve in order to assist his father. But the elementary instruction he had received together with some training in French and Latin were sufficient to enable him to continue his studies without a teacher. He acquired all his scientific training and substantial scholarship by self—instruction—at night, where the tailoring in his father's shops was finished, or during any spare time left after his work as a clerk or private teacher.

Because of his excellent handwriting, Lambert was appointed clerk at the ironworks at Seppois at the age of fifteen. Two years later he became secretary to Johann Rudolf Iselin, editor of the *Basler Zeitung* and later professor of law at Basel Uni9versity. There he had occasion to continue his private studies in the humanities, philosophy, and sciences.

In addition to astronomy and mathematics, Lambert began to take special interest in the theory of recognition. In a letter he reported:

I bought some books in order to learn the first principles of philosophy. The object of my endeavors was the means to become perfect and happy. I understood that the will could not be improved before the mind had been enlightened. I studied: [Christian] Wolf[f] Male—branch “Of the investigation of the truth” [John] Locke “Thoughts of the human mind.” [Lambert probably refers to the *Essay Concerning Human understanding*.] The mathematical sciences, in particular algebra and mechanics, provided me with clear and profound examples to confirm the rules I had learned. Ther by I was enabled to penetrate into other sciences more easily and more profoundly, and to explain them to others, too. It is true that I was well aware of the lack of oral instruction, but I tried to replace this by even more assiduity, and I now thanks to divine assistance reached the point where I can put forth to my lord and lade what I have learned.

In 1748 Lambert became tutor at Chur, in the home of the Reichsgraf Peter von Salis, who had been ambassador to the English court and was married to an Englishwoman. Lambert’s pupils were von Salis’ grandson, evlen-year-old Anton; Anton’s cousin Baptista, also eleven; and a somewhat younger relative, Johann Ulrich von Salis—Seewis, seven years old. Lambert remained as tutor for ten years, a decisive period for his intellectual development. he was able to study intensively in the family library and to pursue his own criticla reflections. he also met many of the friends and visitors of this noble Swiss family. Though Lambert became more refined in this cultivated atmosphere, he remained an original character who did not conform to many bourgeois conventions.

Lambert instructed his young charges in languages, mathematics, geography, history, and the catechism. The Salis family was very pious, and Lambert himself preserved his naturally devout attitude throughout his life. Later, when he lived in Berlin, this caused some embarrassment.

During the years at Chur, Lambert laid the foundation of his scientific work. His *Monatsbuch*, a journal begun in 1752 and continued until his death, lists his main occupations month by month. besides theoretical investigations, Lambert carried out astronomical observations and constructed instruments for scientific experiments. Later, when he had access to improved instruments, he preferred to employ his simple homemade ones.

Lambert’s spirit of inquiry did not remain unnoticed. He was made a member of the Literary Society of Chur and of the Swiss Scientific Society at Basel. On request of the latter he made regular meteorological observations, which he reported in 1755. His first of several publications in *Acta Helvetica* appeared in the same year in volume 2 and death with the measurement of caloric heat.

In 1756 Lambert embarked with Anton and Baptista on a *Bildungreise*, or educational journey, through Europe. Their first stop was at Göttingen, where Lambert attended lectures in the faculty of law and studied works by the Bernoullis and Euler. he talked with Kaestner, with whom he continued to exchange books and letters until his death, and with the astronomer Tobias Mayer. He also participated in the meetings of the Learned Society at Göttingen and was elected corresponding member when he left the city after the French occupation in July 1757 during the Seven Years' War.

The greater part of the following two years was spent at Utrecht, with visits to all the important Dutch cities. Lambert visited the renowned physicist Pieter van Musschenbroek in The Hague, where his first book, on the path of light in air and various media, was published in 1758. Late in 1758 Lambert returned with his pupils to Chur via Paris (where he met d'Alembert), Marseilles, Nice, Turin, and Milan. A few months later he parted from the Salis family.

Seeking a permanent scientific position, Lambert at first hoped for a chair at the University of Göttingen. When this hope came to nothing, he went to Zurich, where he made astronomical observations with Gessner, was elected a member of the city's Physical Society, and published *Die freye Perspektive*. (It is also reported that the Zurich streetboys mocked him for his strange dress.) Lambert then spent some months with his family at Mulhouse.

During the following five years Lambert led a restless, peripatetic life. At Augsburg in 1759 he met the famous instrument maker Georg Friedrich Brander.) Their twelve-year correspondence is available in *Lamberts deutscher gelehrter Briefwechsel*, vol. III.) Lambert also found a published for his *Photometria* and his *Cosmologische Briefe*.

Meanshile plans had been made for a Bavarian academy of sciences, based on the Polan of the Prussian Academy at Berlin. Lambert was chose a salaried member and was asked to organize this academy at Munich. but differecnes arose, and in 1762 he withdrew from the young academy. Returning to Switzerland, he participated as geometer in a resurvey of the frontier between Milan and Chur. he visited Leipzig in order to find a published for his *Neues Organon*, published in two parts in 1764.

In the meantime Lambert had been offered a position at the St. Petersburg Academy. Yet he hoped for a position at the Prussian Academy of Sciences in Berlin, of which he had been proposed as a member in 1791. He arrived in the welcomed by the Swiss group of scientists, among them Euler and Johann Georg Sulzer, the director of the class of philosophy, but his strange appearance and behavior delayed his appointment until 10 January 1765. Frderick the Great is said to have exclaimed, after having seen Lambert for the first time, that the greatest blockhead had been suggested to him for the Academy, nd at first he refused to instate him. Frederick changed his mind later and praised Lambert's "immesurableness of insight." He raised his salary and mad him a member of a new economic commission of the Academy, together with Euler, Sulzer, and Hans Bernard Merian. Lambert also was appointed to the committee for improving land surveying and building administration, and in 1770 he received the title *Oberbaurat*.

As a member of the physical class for twelve years, until his death at the age of forty-nine, Lambert produced more than 150 works for publication. He was the only member of the Academy to exercise regularly the right to read papers not only in his own class, but in any other class as well.

Of Lambert's philosophical writings only his principle works, *Neues Organon* and *Anlage zur Architectonic*, as well as three papers published in *Nova acta erudictrum*, appeared during his lifetime. Although the composition of the main books and papers was done during the period of his appointment to the Berlin Academy in the winter of 1747–1765, Lambert was occupied with philosophical questions as least as early as 1752, as his *Monatsbuch* testifies. During the last ten years of his interest centered on problems in mathematics and physics.

Lambert's philosophical position has been described in the most contradictory terms. R. Zimmermann in *Lambert, der Vorgànger Kants* (Vienna, 1879) tried to demonstrate the germs of Kant's philosophy everywhere in Lambert's writings. Two years later J. Lepsius' *J. H. Lambert* and *Das neud Organon und die Architektonik Lamberts* appeared in Munich. Although more reserved they still interpreted Lambert in terms of Kant. Otto Baentsch arrived at the opposite conclusion in h is *Lamberts Philsophie und sein Stellung zu Kant* (Tübingen—Leipzig, 1902); he believed that Lambert might without harm be omitted from the history of critical philosophy. Kant himself recognized in Lambert a philosopher of the highest qualities; and he expected much from his critical attitude. He had drafted a dedication of the *critique of Pure Reason* to Lambert, but Lambert's untimely death prevented its inclusion.

Lambert's place in the history of philosophy, however, should not be seen only in its relation to Kant. The genesis of his philosophical ideas dates from a time when Kant's major works had yet to be conceived. It was the philosophical doctrines of Leibniz, Christian Wolff, and Locke that exerted the more important influence—insofar as one can speak of influence in connection with a self—taught and wayward man such as Lambert. The Pietist philosophers Adolf Friedrich Hoffman and Christian August Crusisu, antagonists of the Wolffian philosophy, through their logical treatises also had some effect on his thinking.

The two main aspects of Lambert's philosophy, the analytic and the constructive, were both strongly shaped by mathematical notions; hence logic played an important part in his philosophical writing. Following Leibniz' ideas, Lambert early tried to create an *ars characteristica combinatoria*, or a logical or conceptual calculus. He investigated the conditions to which scientific knowledge must be subjected if it is to enjoy the same degree of exactness and evidence as mathematical knowledge. This interest was expressed in tow smaller treatises, *Criterium veritatis* and *über die Methode, die Metaphysik, Theologie und Morla richtiger zu bewisen*, published from manuscript in 1915 and 1918, respectively, by Karl Bopp (*Kantstudien*, supp. nos.

36 and 42). The second of these papers was composed with regard to the prize question posed for 1761 by the Berlin Academy:

What is to be asked is whether metaphysical truths in general, and the first principle of natural theology and morality in particular are subject to the same evidence as mathematical truth; and in case they are not, what then is the nature of their certainty, how complete is it, and is it sufficient to carry conviction?

Lambert's paper, although fragmentary, firmly claimed that theorems and proofs in metaphysics can be given with the same evidence as mathematical ones.

In *Neues Organon, oder Gedanken iiber die Erforschung und Bezeichnung des Waheren und dessen Unterscheidug rom Irrthum und Schein* (Leipzig, 1764) these ideas are further developed. Lambert first dealt with the logical from of knowledge, the laws of thought, and method of scientific proof; he then exhibited the basic elements and studied the systematic character of a theory; he next deveolped (in the section headed "Semiotik") the idea of a characteristic language of symbols to avoid ambiguities of everyday language; and finally, in the most original part of his work called "Phaänomenologie," he discussed appearance and gave rules for distinguishing false (or subjective) appearance from a true (or objective) on that is not susceptible to sensory illusions.

In his second large philosophical work, *Anlage zur Architectonic, order Theorie des Einfachen und des Eesten in der philosophischem und mathematischen Erkenntnis* (Riga, 1771), Lambert proposed a farreaching reform of metaphysics, stemming from discontent with the Wolffian system. Starting from a certain set of concepts which he analyzed, he turned to their a priori construction. Modeled on mathematical procedures, the body of general sciences so constructed was to true both logically and metaphysically. Its propositions would be applied to experience. Each of the particular sciences would be founded on observations and experiments; the rules therby abstracted would have to be joined with the propositions to give a foundation for truth. Leibniz' concept of a prestablized harmony underlay Lambert's ideas, and Lambert followed Leibniz' belier in the best of all possible worlds. But Lambert's subtle discussions of basic notions, axioms, and elementary interrelations heralded the critical period in philosophy; and his logical analysis of a combinatorial calculus is particularly interesting in the development of mathematical logic.

Lambert's work in physics and astronomy must be seen in relation to his general philosophical outlook and his attempts to introduce mathematical exactness and certitude into the sciences. His interest in the paths of comets was stimulated by the appearance of a comet in 1744. While studying the properties of such paths, he discovered interesting geometrical theorems, one of which carries his name. It was later proven analytically by Olbers, Laplace, and Lagrange. In 1770 Lambert suggested an easy method of determining whether the distance between the earth and the sun is greater than the distance from the earth to a given comet.

Lambert's efforts to improve communication and collaboration in astronomy were noteworthy. He promoted the publication of astronomical journals and founded the *Berliner astronomisches Jahrbuch order Ephermeriden*. Many of the articles that he contributed to it were not published until after his death. Lambert also suggested the publication on specialized trigonometrical and astronomical tables in order to reduce laborious routine work. Moreover, he proposed to divide the composition of such tables among several collaborating observatories. He also favored the founding of the Berlin observatory. These suggestions, in line with Leibniz' far-reaching plans for international cooperation of scientific societies, inaugurated a new period of scientific teamwork.

Of special interest among Lambert's astronomical writings—apart from applications of his physical doctrines (see below)—are his famous *Cosmologische Briefe iiber die Einrichtung des Weltbaues* (Augsburg, 1761). Not familiar with the similar ideas of Thomas Wright (published in 1750) and with Kant's *Allgemeine Naturgeschichte und Theorie des Himmels* (1755), Lambert had the idea (in 1749) that what appears as the Milky way might be visual effect of a lensshaped universe. On this basis he elaborated a theory according to which the thousands of stars surrounding the sun constituted a system. Moreover, he considered the Milky Way as a large number of such systems, that is, a system of higher order. Certain difficulties and interpretations concerning the motions of Jupiter and Saturn had led him to conclude that a force must exist outside our planetary system, which must be but a small part of another, much larger system of higher order. These bold speculations, born of the Leibnizian belief in the most perfect of all possible worlds, far transcended astronomy. The whole universe, Lambert postulated, had to be inhabited by creatures like human beings. Hence collisions of heavenly bodies are not to be expected, and the widespread feat that comets (which Lambert also supposed to be inhabited) might destroy the earth was unfounded; the *Cosmologische Briefe* was a great sensation and was translated into French, Russian, and English. Only when William Herschel systematically examined the heavens telescopically and discovered numerous nebulae and "telescopic milky-ways" did it become obvious that Lambert's description was not mere science fiction but to a large extent a bold vision of the basic features of the universe.

Lambert's numerous contributions to physics center on photometry, hygrometry, and pyrometry. Many marked advances in these subjects are traceable to him. In Lambert's fundamental work in the sciences, he (1) searched for a basic system of clearly defined concepts, (2) looked for exact measurements (and often collected them himself), and (3) after establishing them tried to develop a mathematical theory that would comprise these foundations and would result in quantitative laws.

In his famous *Photometria sive de mensure et gradibus luminis*, *colorum et umbrae* (Augsburg, 1760), Lambert laid the foundation for this branch of physics independently of Bouguer, whose writings on the subject were unknown to him. Lambert carried out his experiments with few and primitive instruments, but his conclusions resulted in laws that beat his name. The exponential decrease of the light in a beam passing through an absorbing medium of uniform transparency is often named Lambert's law of absorption, although Bouguer discovered it earlier. Lambert's cosine law states that the brightness of a diffusely radiationg plane surface is proportional to the cosine of the angle formed by the line of sight and the normal to the surface. Such a diffusely radiating surface does therefore appear equally bright when observed at different angles, since the apparent size of the surface also is proportional to the cosine of the said angle.

Lambert's *Hygrometrie* (Augsburg, 1774–1775) was first published in two parts in French as articles entitled *Essai d' hygromeëtrie*. A result of his meteorological studies, this work is mostly concerned with the reliable measurement of the humidity of the atmosphere. The instrument marker G. F. Brander constructed a hygrometer according to Lambert's description. Another product of Lambert's research in meteorology was his wind formula. Now discarded, it attempted to determine the average wind direction on the basis of observations made over a given period.

The *Pyrometrie oder uom maasse des Feuers und der Waàrme* (Berlin, 1779) was Lambert's last book, completed only a few months before his death; his first publication had also dealt with the question of measuring heat. It is characteristic of him that he dealt not only with radiation but also with reflection of heat, although the latter could not yet be demonstrated, and his results could only have been preliminary in in nature. Lambert also took into consideration the sensory effect of heat on the human body and tried to give a mathematical formulation for it. Similarly, his work in acoustics, on speaking tubes, touched on the physical as well as on the psychophysical aspects of the problems.

In mathematics Lambert's largest publication was the *Beyträge zum Gebrauch der Mathematik und deren Anwendung* (3 pts. 4 vols., Berlin, 1765–1772). This is not at all a systematic work but rather a collection of papers and notes on a variety of many topics in pure and applied mathematics.

One of Lambert's most famous results is the proof of the irrationality of π and e. It was based on continued fractions, and two such fractions still beat his name. Of importance also is Lambert's series in which the coefficient 2 occurs only when the exponent is a prime number. Although it was expected that it might be useful in analytic number theory, it was not until 1928 that Norbert Wiener was able to give a proof of the prime number theorem employing this type of series. Lambert himself was interested in number theory and developed a method of determining the prime factors of a given (large) number and suggested a simplified arrangement for factor tables.

Many of Lambert's investigations were concerned with trigonometry and goniometry. He studied the hyperbolic functions and introduced them in order to reduce the amount of computation in trigonometric problems. He solved goniometric equations by infinite series, and he worked out a tetragonometry—a doctrine of plane quadrangles—corresponding to the common trigonometry. That he also discovered a number of theorems in the geometry of conic sections has already been mentioned in connection with his astronomical work.

Lambert's second book, *Die freye Perspektive*, *oder Anweisung*, *jeden perspektivischen Aufriss von freyen Stuücken und ohne Grundriss zu verfertigen* (Zurich, 1759; 2nd ed. 1774), was also published in French (Zurich, 1759). Intended for the ariest wishing to give a perspective drawing without first having to construct a ground plan, it is nevertheless a msterpiece in descriptive geometry, containing a wealth of geometrical discoveries. In this work Lambert proved himself a geometer of great intuitive powers. In the generality of his outlook, as in certain specific aspects, his work resembles that of Monge later on, usually considered the founder of descriptive geometry as a distinct branch of mathematics. Lambert's investigations of possible constructions an ellipse from five given point, was similar in spirit to the program of Poncelet and J. Steiner two generations later.

Lambert contributed significantly to the theory of map construction. For the first time the mathematical conditions for map projections (to preserve angles and area) were stated, although analytically superior formulations were later given by Lagrange, Legendre, and Gauss. More important, Lambert made practical suggestions on how, for different purposes, either one of these contradicting conditions could best be satisfied. He also described construction to determine the true distance between two places on a map drawn according to one of his projections. Lambert's map projections are still basic for the modern theory in this field.

One of Lambert's most important contributions to geometry was his posthumously published *Theorie der Parallel-Linien*. Here he returned to the famous question that had baffled mathematicians since Euclid: Is it not possible to give a proof for Euclid's axiom of parallels? As a starting point Lambert chose a quadrangle having three right angles, and assumed in turn the fourth angle to be a right angle, an obtuse angle, or an acute angle. He showed that the first assumption is equivalent to Euclid's postulate, and that the second leads to a contradiction (assuming each straight line to possess an infinite length). Having attempted to display a contradiction in case of the third assumption using the same line of argument unsuccessfully, he tried a different mode of attack but overlooked that his "proof" implicitly contained an assumption equivalent to his hypothesis. Obviously not satisfied with his investigations, Lambert did not publish them; yet he had already arrived at remarkable results. He had discovered that under the second and third assumption an absolute measure of length must exist and that the area of a triangle in these cases must be proportional to the divergence of its angle sum from two right angles. He noticed that the second assumption would correspond to the geometry of the sphere; and he speculated that the third assumption might be realizable on an imaginary sphere. An example for this last case was not given until the latter half of the nineteenth century by Beltrami, after this non-Euclidean geometry had been studied in particular by Lobachevsky. The quadrangle used as starting point by Lambert is called Saccheri's quadrangle . Whether Lambert was directly familiar with the investigations of this Italian mathematician is not known.

Lambert's work in non-Euclidean geometry had been overlooked until it was republished by F. Engel and Staàckel in their *Theorie der Parallellinien von Euklid bis auf Gauss* (Leipzig, 1895).

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