Professor Jean Baptiste Joseph Fourier (1768 – 1830)

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Known for: Fourier series, Fourier transform, Fourier's law of conduction

Jean Baptiste Joseph Fourier (21 March 1768 – 16 May 1830) was a French mathematician and physicist best known for initiating the investigation of Fourier series and their applications to problems of heat transfer and vibrations. The Fourier transform and Fourier's Law are also named in his honour. Fourier is also generally credited with the discovery of the greenhouse effect.

Life

Fourier was born at Auxerre (now in the Yonne département of France), the son of a tailor. He was orphaned at age eight. Fourier was recommended to the Bishop of Auxerre, and through this introduction, he was educated by the Benvenistes of the Convent of St. Mark. The commissions in the scientific corps of the army were reserved for those of good birth, and being thus ineligible, he accepted a military lectureship on mathematics. He took a prominent part in his own district in promoting the French Revolution, serving on the local Revolutionary Committee. He was imprisoned briefly during the Terror but in 1795 was appointed to the École Normale Supérieure, and subsequently succeeded Joseph-Louis Lagrange at the École Polytechnique.

Fourier went with Napoleon Bonaparte on his Egyptian expedition in 1798, and was made governor of Lower Egypt [2] and secretary of the Institut d'Égypte. Cut off from France by the English fleet, he organized the workshops on which the French army had to rely for their munitions of war. He also contributed several mathematical papers to the Egyptian Institute (also called the Cairo Institute) that Napoleon founded at Cairo, with a view of weakening English influence in the East. After the British victories and the capitulation of the French under General Menou in 1801, Fourier returned to France.

In 1806 Napoleon appointed him prefect of the Department of Isère in Grenoble, where he oversaw road construction and other projects. It was while at Grenoble that he began to experiment on the propagation of heat. He presented his paper On the Propagation of Heat in Solid Bodies to the Paris Institute on December 21, 1807. He also contributed to the monumental Description de l'Égypte.

Fourier moved to England in 1816. Later he returned to France, and in 1822 succeeded Jean Baptiste Joseph Delambre as Permanent Secretary of the French Academy of Sciences. In 1830, he was elected a foreign member of the Royal Swedish Academy of Sciences.

In 1830, his diminished health began to take its toll: Fourier had already experienced, in Egypt and Grenoble, some attacks of aneurism of the heart. At Paris, it was impossible to be mistaken with respect to the primary cause of the frequent suffocations which he experienced. A fall, however, which he sustained on the 4th of May, 1830, while descending a flight of stairs, aggravated the malady to an extent beyond what could have been ever been expected. Shortly after this event, he died in his bed on 16 May, 1830. Fourier was buried in the Père Lachaise Cemetery in Paris, a tomb decorated with an Egyptian motif to reflect his position as secretary of the Cairo Institute, and his collation of the landmark Description de l'Égypte. His name is one of the 72 names inscribed on the Eiffel Tower.

Théorie analytique de la chaleur

In 1822 Fourier presented his work on heat flow in Théorie analytique de la chaleur (The Analytic Theory of heat), in which he based his reasoning on Newton's law of cooling, namely, that the flow of heat between two adjacent molecules is proportional to the extremely small difference of their temperatures. This book was translated with editorial 'corrections', into English 56 years later by Freeman (1878). The book was also edited, with many editorial corrections, by Darboux and republished in French in 1888.

There were three important contributions in this work, one purely mathematical, two essentially physical. In mathematics, Fourier claimed that any function of a variable, whether continuous or discontinuous, can be expanded in a series of sines of multiples of the variable. Though this result is not correct, Fourier's observation that some discontinuous functions are the sum of infinite series was a breakthrough. The question of determining when a Fourier series converges has been fundamental for centuries. Joseph Louis Lagrange had given particular cases of this (false) theorem, and had implied that the method was general, but he had not pursued the subject. Johann Dirichlet was the first to give a satisfactory demonstration of it with some restrictive conditions.

One physical contribution in the book was the concept of dimensional homogeneity in equations; i.e. an equation can be formally correct only if the dimensions match on either side of the equality. Fourier also developed dimensional analysis, the method of representing physical units, such as velocity and acceleration, by their fundamental dimensions of mass, time, and length, to obtain relations between them. The other physical contribution was Fourier's proposal of his partial differential equation for conductive diffusion of heat. This equation is now taught to every student of mathematical physics.

Determinate equations

Fourier left an unfinished work on determinate equations that was edited by Claude-Louis Navier and published in 1831. This work contains much original matter — in particular, there is a demonstration of Fourier's theorem on the position of the roots of an algebraic equation. Joseph Louis Lagrange had shown how the roots of an algebraic equation might be separated by means of another equation whose roots were the squares of the differences of the roots of the original equation. François Budan, in 1807 and 1811, had enunciated the theorem generally known by the name of Fourier, but the demonstration was not altogether satisfactory. Fourier's proof is the same as that usually given in textbooks on the theory of equations. The final solution of the problem was given in 1829 by Jacques Charles François Sturm.

Discovery of the "greenhouse effect"

In the 1820s Fourier calculated that an object the size of the Earth, and at its distance from the Sun, should be considerably colder than the planet actually is if warmed only by the effects of incoming solar radiation. He examined various possible sources of the additional observed heat in articles published in 1824 and 1827. While he ultimately suggested that interstellar radiation might be responsible for a large portion of the additional warmth, Fourier's consideration of the possibility that the Earth's atmosphere might act as an insulator of some kind is widely recognized as the first proposal of what is now known as the greenhouse effect.

In his articles Fourier referred to an experiment by de Saussure, who lined a vase with blackened cork. Into the cork, he inserted several panes of transparent glass, separated by intervals of air. Midday sunlight was allowed to enter at the top of the vase through the glass panes. The temperature became more elevated in the more interior compartments of this device. Fourier concluded that gases in the atmosphere could form a stable barrier like the glass panes. This conclusion may have contributed to the later use of the metaphor of the 'greenhouse effect' to refer to the processes that determine atmospheric temperatures. Fourier noted that the actual mechanisms that determine the temperatures of the atmosphere included convection, which was not present in de Saussure's experimental device.

Works

1 Fourier, Joseph (1822). Théorie analytique de la chaleur. Paris: Firmin Didot Père et Fils.

2 Fourier, Joseph (1824). Annales de chimie et de physique. 27. Paris: Annals of Chemistry and Physics. pp. 236–281.

3 Fourier, Joseph (1827). Mémoire sur la température du globe terrestre et des espaces planétaires. 7. Memoirs of the Royal Academy of Sciences of the Institut de France. pp. 569–604.

4 Fourier, Joseph (1827). Mémoire sur la distinction des racines imaginaires, et sur l'application des théorèmes d'analyse algébrique aux équations transcendantes qui dépendent de la théorie de la chaleur. 7. Memoirs of the Royal Academy of Sciences of the Institut de France. pp. 605–624.

5 Fourier, Joseph (1827). Analyse des équations déterminées. 10. Firmin Didot frères. pp. 119–146.

6 Fourier, Joseph (1827). Remarques générales sur l'application du principe de l'analyse algébrique aux équations transcendantes. 10. Paris: Memoirs of the Royal Academy of Sciences of the Institut de France. pp. 119–146.

7 Fourier, Joseph (1833). Mémoire d'analyse sur le mouvement de la chaleur dans les fluides. 12. Paris: Memoirs of the Royal Academy of Sciences of the Institut de France. pp. 507–530.

8 Fourier, Joseph (1821). Rapport sur les tontines. 5. Paris: Memoirs of the Royal Academy of Sciences of the Institut de France. pp. 26–43.