JOSEPH FOURIER

While working on the flow of heat, French mathematician [**Jean Baptiste**] **Joseph Fourier** (March 21, 1768 – May 16, 1830) discovered the equation for it that now bears his name. To solve the problem of finding this equation he showed that many functions of a single variable could be expanded as a series of sines of multiples of the variable.

Fourier published a mathematical theory of heat conduction that was entirely independent of the caloric hypothesis, then the most influential theory of what heat was and how it worked. He based the study of the theory of heat on linear partial differential equations that characterized the transmission of heat. To find the conduction of heat through a given body, when its boundaries are at particular temperatures, the heat diffusion equation can be expressed as a sum of simpler trigonometric components (Fourier series).

Fourier, the son of a tailor, born in Auxerre, was orphaned at the age of eight. A lady, who admired his manners and precocious natural abilities, later recommended him to the bishop of Auxerre. Through the latter's influence, Fourier was admitted in 1780 to École Royale Militaire of Auxerre, run by the Benedictines of the Convent of St. Mark. There he discovered that his real talent was in mathematics. Fourier wanted to become a soldier and sought to take the examination for the artillery. The minister rejected his application, declaring: "Fourier, not being noble, could not enter the artillery, although he were a second Newton." Disappointed, Fourier repaired to the abbey of St. Benoît-sur-Loire, planning to serve his novitiate. There he exercised his insatiable curiosity in the study of mathematics. He left the abbey for Paris to present a paper on algebraic equations at the Académie Royale des Sciences in 1789. The following year he was appointed a mathematics teacher at the École Royale Militaire where he had been a student.

Fourier was active politically during the upheaval of the French Revolution. Though he initially embraced the principles of the Revolution with enthusiasm, he became unhappy with its excesses and attempted to resign from his position on the local Revolutionary Committee but was unable to withdraw. In July 1794 Fourier sided with the wrong faction and was arrested and imprisoned. He was certain he would be guillotined but instead Robespierre was executed and Fourier was released. The next year Fourier became a student and a teacher of the newly opened École Normale in Paris, which was to serve as a model for teacher-training schools. Among Fourier's mathematics teachers were Joseph-Louis Lagrange, Pierre-Simon Laplace, and Gaspard Monge. Three years later Fourier succeeded Lagrange at the École Polytechnique in the chair of analysis and mechanics.

In 1798 Fourier accompanied young General Napoleon Bonaparte on his Eastern expedition. Napoleon dreamed of restoring France to its ancient splendor. He realized to accomplish his goal it would be necessary to appeal to science, to literature, and to the fine arts. He appointed Fourier governor of Lower Egypt. Cut off from France by the English fleet, Fourier contributed several papers to the Egyptian Institute, which Napoleon founded immediately after conquering Cairo, with Monge serving as its first president and Fourier its perpetual secretary. In Egypt Fourier demonstrated his considerable talent for organization, which Napoleon did not forget when he seized absolute power in France. After Fourier returned to Paris Napoleon made him an offer that was actually a command to serve as the Prefect (much like the governor of a state) of the Department of Isère in Grenoble. While occupying this position Fourier oversaw the operation of draining the swamps of Bourgoin and the construction of a new highway between Grenoble and Turin.

It is from Grenoble that the principal writings of Fourier are dated. He was also busy working on a book *Description of Egypt*, which was not completed until 1810. Fourier's most significant work was

his mathematical study of the analytical theory of heat. Before Fourier the phenomenon of heat was rarely studied and so in a very real sense he invented a new science. Fourier completed his now famous paper *On the Propagation of Heat in Solid Bodies*, which he read to the Paris Institute on December 21, 1807. He maintained that heat concentrated into a certain point of a solid body, communicates itself by way of conduction, first to nearby particles, then gradually to all regions of the body. Fourier was thus able to write out the differential equations for the propagation of heat.

His paper caused considerable controversy. While acknowledging the novelty and importance of the paper, the committee set up to judge his work, Laplace, Lagrange and Adrien-Marie Legendre, objected to the way he had arrived at the equations, the use of expansions of functions as trigonometric series, now called Fourier series, and that his processes of integration were not well established. They also had problems with Fourier's lack of rigor. His genius for intuition led him to conclusions that he was unable to support logically. Even so, he was awarded a prize for his work. He fought for 15 years to get this seminal paper published. Finally in 1822, the Académie des Sciences published Fourier's essay *Théorie analytique de la chaleur* (Analytical theory of heat). In it he based his theory on Newton's law of cooling, which states that the flow of heat between two adjacent molecules is proportional to the infinitely small differences in their temperatures.

When Napoleon was defeated and went into exile in Elba, Fourier removed any mention of the deposed emperor from the second edition of *Description of Egypt*. When Napoleon escaped from Elba and marched towards Grenoble with an army, Fourier unsuccessfully tried to talk the people of the region into opposing Napoleon and to give their allegiance to the king. Napoleon was very angry with Fourier, but somehow the latter patched things up and was even appointed Prefect of the Rhône. Fourier soon resigned when he was given orders to remove all administrators with royalist sympathies from their posts. Even so, Napoleon awarded Fourier a pension, which he never received because shortly

thereafter Napoleon was defeated for the last time.

The greatest influence on Fourier's life was his time in Egypt, where he developed his lifelong obsession with heat. In his last years, in order to guard against slight attacks of rheumatism, he swathed himself mummy-like in an overheated apartment, even in summer. He believed that desert heat was the ideal condition for a healthy life. Subsequent events would seem to imply that he was wrong. While in Egypt and Grenoble Fourier had experienced aneurysms of the heart. He also experienced frequent suffocations and on May 4, 1830 sustained a fall while descending a flight of stairs that aggravated his condition. He refused to combat his symptoms with anything other than patience and heat. On May 16, he experienced a crisis and cried out to his doctor, "Quick, quick, some vinegar, I am fainting!" and then he died.

Quotation of the Day: "The differential equations of the propagation of heat express the most general conditions, and reduce the physical questions to problems of pure analysis, and this is the proper object of theory." – Joseph Fourier