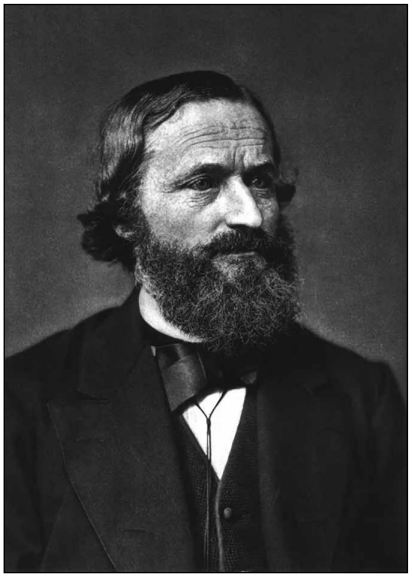
Gustav Robert Kirchhoff

In the 19th century, new electrical, magnetic, and thermal phenomena were observed, eventually leading to the development of electromagnetic theory and thermodynamics as new theories of physics. These theories were mainly developed by physicists in France, Great Britain, and Germany. Gustav Robert Kirchhoff was one of the German physicists involved in this process and thus became one of the founders of mathematical physics, at least in Germany. Together with Robert Wilhelm Bunsen, he developed optical spectroscopy and examined the spectrum of the sun, becoming one of the founders of astrophysics. Kirchhoff introduced the black body and discovered the law of thermal radiation. However, electrical engineers know Kirchhoff because of his fundamental contributions to electrical circuits and the well-known Kirchhoff's laws.



Gustav Robert Kirchhoff (1824–1887)

Gustav Robert Kirchhoff was born on March 12, 1824, in Königsberg (now Kaliningrad, Russia) as the son of Friedrich Kirchhoff, a lawyer, and Johanna Henriette Wittke [2]. After he left the Kneiphöfische Gymnasium at age 18, Kirchhoff studied mathematics and physics at the Albertus University of Königsberg. Under the scientific direction of Franz Ernst Neumann, he worked since 1843 in the mathematical-physical seminar, which was founded by Carl Gustav Jacob Jacobi. In 1847, Kirchhoff was honored for solving a philosophical faculty prize task, using the revised manuscript as a dissertation. In the same year he moved to the Friedrich-Wilhelms-Universität Berlin, where he received his habilitation (venia legendi) and became a private lecturer (Privatdozent). In 1850, at the age of 25, Kirchhoff transferred to the University of Breslau (now Wrocław, Poland), but as early as 1854 he followed his friend Robert Wilhelm Bunsen to the University of Heidelberg, where he spent his most fruitful years from an academic point of view. In 1857, Kirchhoff married Clara Richelot, the daughter of his Former Mathematics Professor F. J. Richelot. Finally, in 1875, Kirchhoff received an exceptional and honorable vocation to the Prussian Academy of Sciences and at the same time to the University of Berlin. Kirchhoff died in Berlin in 1887 at the age of 63 [15].

It is not the place to present all contributions to theoretical and applied physics, we only discuss his pioneering scientific work in electromagnetics, which remained a research area until the end of his life. As early as 1845, while still a student at the Neumann Seminar, Kirchhoff [6] published his first scientific paper "On electrical conduction in a thin plate and in particular in a circular plate" in the famous Poggendorff's Annalen of Physics and Chemistry. A very general formulation of the two Kirchhoff laws for linear DC networks is included in the appendix of this paper but already in the introduction of this paper he pointed out that "The type of distribution can be determined theoretically according to the principles established by Ohm." Actually, the physical laws for DC networks were developed by Ohm [10] and formulated verbally in his seminal original book. Kirchhoff's first work also shows that he was interested in the development or further development of physical measuring devices. It is interesting that Kirchhoff formulated his famous laws in order to analyze a resistance measuring bridge which was a modified version of Wheatstone's bridge published in 1843 [3]. The fundamental importance of Kirchhoff's laws was first discovered by Poggendorff [11], which greatly simplified or made possible the analysis of networks with nodes connected by more than two branches. Poggendorff [11] mentioned that he and Wilhelm Weber had serious problems analyzing the Wheatstone bridge. Kirchhoff [8], [9] presented the realization of a resistance measurement bridge that put

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Wheatstone's idea into practice, which is why it was for a time called the Wheatstone-Kirchhoff bridge.

The above-mentioned prize task of the University of Königsberg was related to Neumann's contributions to circuits with inductive circuit elements, in which Kirchhoff presented a work "About the determination of the constants on which the intensity of the induced currents depends" which corresponded in content to his dissertation [2].

While Kirchhoff's laws [6] have been well known to almost all physicists and electrical engineers since their first publication in 1845, the results of Kirchhoff's 1847 paper "On the Solution of the Equations Arising from the Study of the Linear Distribution of Galvanic Currents" [7] have long been overlooked. It was only 40 years later that James Clerk Maxwell discussed Kirchhoff's findings in his famous book, "Treatise on Electricity and Magnetism" but without further reactions. Veblen [14] was the first who pointed out in 1916 the Cambridge Colloquium that Kirchhoff's "paper is doubtless the first important contribution to the theory of linear graphs" which was emphasized by Weyl [17] and Franklin [5]. Although graph theory studies on electrical networks were published by Cauer [1], Foster [4], and a few others, it was not until the mid-1950s that extensive research on Kirchhoff's concept began [13], [16]. In particular, it turned out that Kirchhoff's topological ideas can be further developed to general topological formulas for linear network functions and in the context of the synthesis of electrical networks. Thus, topological aspects of electrical circuit theory became an intense research area for many years.

Although Kirchhoff mainly devoted himself to other physical problems after moving to Heidelberg, electromagnetic phenomena remained an interesting research area for him. In 1857, he theoretically studied the movement of electricity in conducting wires [8], [9], which became of practical interest with regard to telegraphic transmission using submarine cables. Kirchhoff concluded that electricity travels in the form of a wave with the speed $c/2$ (c: speed of light), which is not far from today's value. He was the first to show that electrical effects propagate at speeds close to the speed of light. Later he studied electrical conductivity in more general situations. In 1864, on the theory of the discharge of a Leyden jar, which became of interest with regard to wireless telegraphy. Due to his interest in technical problems, he was one of the 35 founders of the world's first association of electrical engineers in Berlin in 1879. Together with Werner Siemens, Paul David Fischer, a secretary of the Reich Postal Ministry, and Wilhelm Strecker, a member of the German Reich's Ministry of Railways, Kirchhoff took over the management of the "Elektrotechnischer Verein."

At the end of 1887, Kirchhoff was posthumously awarded the "Prix Jannsen" by the French Académie des Sciences in Paris for his exceptional scientific work. The medal was sent to his widow on April 19, 1888 [15].

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