Sadi Carnot

In trying to understand the limits of efficiency of steam engines, French engineer **Sadi Nicolas Léonard Carnot** (June 1, 1796 – August 24, 1832) observed that in any heat engine there would always be rejected heat– and the net work done would be the difference between the heat absorbed and that rejected. A heat engine is a cyclic process that absorbs heat and does work on the surroundings. “Cyclic” means that the system returns to its initial state at the end of each cycle so that there is no permanent change in the system.

Born in the Palais du Petit-Luxembourg, Sadi was named after a medieval Persian poet and philosopher Sa´di of Shiraz. Carnot’s first teacher was his father, geometer and engineer Lazare Carnot, who taught him mathematics and science. At age 16 Sadi entered the École Polytechnique in Paris and after graduating took the two-year course in military engineering at the École du Génie at Metz. He took leave from the military to attend classes at the Sorbonne and the Collège de France in Paris, where he was interested in industrial problems, particularly the study of gases.

Carnot developed a passion for steam engines. He was annoyed that France had fallen so far behind in the design of such valuable machines. His enthusiasm for engines led him to formulate a theory of the relation between heat and mechanical energy, found in his only published work, *Réflexions sur la puissance motrice du feu* (*Reflections on the Motive Power of Heat*, 1824). In it he reviewed the industrial, political, and economic importance of the steam engine, and showed that the work produced by the machine is proportional to the heat transferred from the boiler to the condenser. He considered an idealized steam engine, frictionless, with its working substance passing from heat source to heat sink through a series of equilibrium states, in such a way that it is truly reversible. The pressure – volume changes in it constitutes a *Carnot cycle.* In the cycle, steam undergoes four successive changes: 1. it receives heat, expanding at high temperature; 2. it delivers work during the reversible adiabatic expansion (i.e. it changes its volume or pressure without losing or gaining heat); 3. it rejects heat (to the heat sink) during compression at low temperature; and 4. it receives work during the reversible adiabatic compression.

Carnot formulated the principle that in general work can only be obtained from heat by a transfer from a warmer to a colder body. Thus, he became the first to show the quantitative relationship between work and heat. *Carnot's Principle*, a form of the Second Law of Thermodynamics, anticipated the work of James Joule, Lord Kelvin and others. Carnot proved a theorem, which states that maximum efficiency of a heat engine could be obtained only by a reversible engine, an ideal that could never be achieved. This meant that heat transferred into or out of the heat engine would only occur at constant temperatures. Civil engineer Emil Clapeyron rescued Carnot's book from obscurity when he published an analytic reformation of it in 1834. Clapeyron's ideas were later incorporated into the thermodynamic theory of Rudolf Clausius and J.J. Thomson.

Carnot died of cholera at the age of 36. As was the practice at the time, his personal effects were burned. Some of his notes, which escaped destruction, indicated that he was moving away from the caloric theory towards modern heat theory. The entries contained details of experiments he intended to perform. Some of these were identical to those carried out by Joule twenty years later. It appears that Carnot arrived at the notion that heat is essentially work, or work that has changed form. This is the reason that he is considered the founder of the science of thermodynamics, which states that energy can never disappear; it can only be altered into other forms of energy. Carnot's unpublished notes led Lord Kelvin to confirm and extend the science of thermodynamics in 1850.

Quotation of the Day: “There is … one supremely important law which is only statistical; this is the second law of thermodynamics. It states, roughly speaking, that the world is growing continuously more disorderly.” – Bertrand Russell