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James Prescott Joule (1818-1889): Converting Work into Heat

How do you get heat out of mechanical work? James Prescott Joule developed revolutionary ideas on energy and temperature. He established the 'Mechanical Equivalent of Heat' which included a constant describing the conversion of heat into mechanical work. The International unit of energy, the joule, is named in his honour. The Museum's collections include most of Joule's scientific apparatus.

James Joule was born into a wealthy brewing family in Salford, the son of Benjamin and Alice. He was initially educated at home and then, at the age of 16, began to study under John Dalton, the eminent Manchester scientist. Joule soon began to conduct electrical and magnetic experiments at a laboratory built in the cellar of his father's home in Pendlebury. He was fascinated by the possibility that electro-magnets might become useful as sources of industrial power. He began to link together electricity, heat and mechanical power by observing the transformations they went through.

In 1840, Joule published a paper in the *Proceedings of the Royal Society* describing the first of the laws with which he is associated. Now called Joule's Law**,** it states that heat is produced in an electrical conductor. In the experiments behind this law, he had placed coils of different kinds of metal in jars of water and measured the change in temperature. He was elected a member of the Manchester Literary & Philosophical Society in 1842 and held several offices before being elected President in 1860.

In 1843, he read a paper titled 'On the Calorific Effects of Magneto-Electricity and on the Mechanical Value of Heat' at a meeting of the British Association in Cork. This determined the physical constant now known as 'J', or Joule's Equivalent and showed that heat was a form of energy.

Joule's father moved from Pendlebury to Whalley Range and built him a new laboratory. However, James used the cellar of the family brewery to carry out more exact experiments on the value of 'J', as determined by the friction of water, in order to minimise temperature fluctuations. He used minutely accurate thermometers and a travelling microscope to etch the scale of each thermometer precisely. These were made for him by the well-known Manchester scientific instrument maker, J. B. Dancer. He worked in the brewery during the day and also carried out research to improve the quality of beer in his laboratory

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He gave a short verbal description of his results to the 1847 British Association meeting in Oxford, where he met William Thomson (later Lord Kelvin), who was Professor of Natural Philosophy at Glasgow University. This acquaintance 'quickly ripened into a life-long friendship'. Later the same year, Joule married Amelia Grimes and the couple toured Switzerland. Thomson later recalled having met Joule there by chance and found him about to measure the temperature of the Sallanches waterfall – on his honeymoon. Joule published the results of further experiments on the production of heat by friction in the Royal Society's *Philosophical Transactions* in 1850 and gave the most accurate determination of the constant yet. He also gave a detailed description of the mechanical construction of the experimental set-ups and the design of the paddlewheel for churning the water, as well as a minute account of how to perform the experiment properly. The Royal Society awarded him both a Royal and later a Copley medal for his experiments, a very unusual event.

After working with Thomson between 1852 and 1859, he described the Joule-Thomson effect, whereby an expanding gas is cooled as work is done to separate the molecules. Amelia died in 1854, leaving a son and daughter, having lost a baby son only weeks before. Joule threw himself into his work but his heart was no longer in it. The family funds finally ran out in 1875, although he was granted a Civil List pension three years later. In the years that followed, he was often ill and he died in 1889 in Sale.

Joule's success in developing a conceptual framework about energy owed much to his considerable experimental skills. He was not the first to determine the mechanical equivalent of heat; Count Rumford had produced a wildly inaccurate value working in Bavaria in the 1790s. Joule backed up his figure with a large variety of careful experimental data, which enabled him to force his view on the world of science. James Joule was also an inventor. Amongst his many inventions are 'arc welding' (electrical welding) and the displacement pump. Joule preferred to work from home and never took an academic appointment, despite close ties with Owens College, the precursor of the University of Manchester.

Joule's paddlewheel experiment on the friction of water was re-worked by a group of research students at the University of Oldenburg, Germany, between 1990 and 1992, based on Joule's 1850 description and the original apparatus. This research has shown the extent of Joule's skills in calibrating and reading thermometers, and in calculating specific heats of the metals used, all of which came from his experience of the use of the thermometer and the working conditions in brewing.

For more information:

Visit The Museum's Manchester Science Gallery and Collections Centre.
The *Joule and Energy* microsite on the Museum's website: http://www.msim.org.uk/joule/index.htm

Read
Cardwell, Donald. *James Joule*. Manchester, UK: Manchester University Press, 1989.
Sibum, Heinz Otto. 'Reworking the Mechanical Value of Heat: instruments of precision and gestures of accuracy in early Victorian England'. *Studies in the History and Philosophy of Science* 26/1 (1995): 73-106.