

## The hard work of experimenting: James Prescott Joule and the mechanical equivalent of heat.

Manchester, in the early 1840s. Manchester was a busy industrial town in these days, actually, it could be named as the industrial center of England, and in those days, this was synonymous with the industrial center of the world. James Prescott Joule, a young owner of a brewery, was walking towards his factory. Well, actually it was still his father's factory, but he had taken responsibility some years ago already. While he was walking through the street, he appeared absent minded, and there was a pretty good, even though not that obvious reason for this absentmindedness: His brewery was doing well, actually, the beer he produced was among the most popular ones in the town. However, there was something completely different that puzzled and to some extent troubled Joule.

Recently, he had learned about a newly invented machine, a so-called electrical motor. This device was based on an invention made by the well known scientists Michael Faraday, and someone in Russia was said to have propelled a boat on a river with this new engine. Claims were that this device was able to carry out work at literally no cost, and Joule, who was interested in scientific and technological achievements since his childhood days, had one made immediately. Actually, he had several motors examined in the course of the last months, however, they did not work as he had hoped and turned out to consume too much of the expensive zinc in the batteries. From his investigations, it had become clear to Joule that this could not be an economic useful replacement for the steam engines in his factory. Yet, what puzzled him and made him uncomfortable was the heat that was produced by these electrical motors. Where did it come from? And if it was produced by electricity, what happened to the electricity? Joule shivered, and rubbed his hands to get them a bit warmer. He stopped dead when a thought struck his mind: Could it be...? Was there a possibility that a certain amount of mechanical force was transformed into a respective amount of heat? Could that also be the case

with electricity? He started to think about how to examine these connections.

About three years after the day the initial idea had struck Joule, he was sitting in his office and looking back at his achievements with respect to this experiment: He had designed a machine that could transform mechanical force into heat. This did not sound so difficult, but he had a machine that was really efficient in transforming mechanical work into heat.

A local instrument maker had built the device that basically looked like a toy-sized version of his brewers' vessel: It consists of a copper vessel that was filled with 6 l of water. Inside the vessel there was an axis with brass paddles to mix the water. Additionally, there were also fixed paddles that helped to produce a larger friction in the water – meanwhile he could use weights of almost 25 kg altogether to move the mechanism, and the friction was so large that the weights went down very slowly, actually they were slower than a piece of paper was falling. Winding them up again however was hard work, way too tough for James who had a weak health since his childhood days, and who was not allowed to do physical working whatsoever. Besides, he was the owner of a brewery and certainly a hardworking man, but no one who would carry out work that would make him sweat. But one of the workmen from his factory had developed substantial competences in winding up the weights without wasting too much time and without putting too much stress on the cord that connected the weights with the axis.

Every day Joule's responsibilities in the business permitted him to spend some time in the cellar of his brewery, he had his workman down there winding up the weights and letting them go down again, and after twenty times, he measured the temperature of the water. He was well aware that his workmen were talking about the weird interest of their boss, however, he did not care. He felt that he was going to make a major discovery, and that this would be an important contribution to the sciences. He had already presented preliminary results of his experiments to the local scientific

ic society, the Manchester Phil. and Lit. And he even had attended a meeting of the British Association for the Advancement of the Sciences and presented his results. Yet the scientists at these meetings were not really interested in his findings and did not respond – actually they did not even criticize his results even though they were far from being satisfactory. Joule moaned, raised from his desk and made his way once again in the factory where he would call the workman who would to the winding up of the weights. However, there was something different very day: John Benjamin Dancer, his instrument maker, had brought him two new thermometers which were much more sensitive than the previous ones. Joule was an expert in reading thermometers, this was one of the qualifications a person in the brewing business should have. However, these instruments were different. They had markings for every tenth of a degree, and the distances between two markings were still easily visible. These instruments would enable him to reach a new precision, and that would be decisive with respect to his experiments.

In the cellar, Joule shivered and rubbed his hands, and he smiled as he remembered the very moment when the first idea of his experiment had struck him. It had been a long and laborious time since then, and the experiment had gone through several modifications. He inserted the thermometer into the water and waited for being able to read the temperature, then he controlled the room temperature and gave his workman a nod – the experiment could start. Some thirty minutes later, Joule reinserted the thermometer into the water and waited for the reading to stabilize whilst the workman was standing behind him, breathing hard after the work he had carried out. Joule read the instrument and noted the value, and then they would wait another thirty minutes to estimate the heat transfer between the vessel and the room, after that there would be time enough for another run.

James Prescott Joule, the owner of a Manchester brewery, succeeded in determining experimentally the value of the mechanical equivalent of heat. It took almost eight years from his first attempt to his publication

in the prestigious Transactions of the Royal Society London. His work on the mechanical equivalent of heat was crucial for the development of the concept of energy (how mechanical force was called by then) and the principle of energy conservation. Due to his achievements, Joule was honored particularly, the unit of energy was given his name while he was still alive, so far, he is the only scientist who was ever honored in such a manner during his lifetimes.

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**Story: The Hard work of experimenting: James Prescott Joule and the mechanical equivalent of heat** was written by Peter Heering, with the support of the Lifelong Learning Programme of the European Union and the University of Flensburg, Germany.