

PHYSICS

The Mechanical Equivalent of Heat

"A Classic of Science"

Joule Startled the 1845 British Association Meeting By Declaring That Heat Can Be Measured in Foot Pounds

THE SCIENTIFIC PAPERS OF JAMES PRESCOTT JOULE, *Published by the Physical Society of London. London: 1884. The following are exact reprints of the original publications.*

ON THE MECHANICAL EQUIVALENT OF HEAT. By James P. Joule. *Brit. Assoc. Rep. 1845, Trans. Chemical Sect. p. 31. Read before the British Association at Cambridge, June, 1845.*

THE AUTHOR gave the results of some experiments, in order to confirm the views he had already derived from experiments on the heat evolved by magneto-electricity, and from experiments on the changes of temperature produced by the condensation and rarefaction of elastic fluids. He exhibited to the Section an apparatus consisting of a can of peculiar construction filled with water. A sort of paddle-wheel was placed in the can, to which motion could be communicated by means of weights thrown over two pulleys working in contrary directions. He stated that the force spent in revolving the paddle-wheel produced a certain increment in the temperature of the water; and hence he drew the conclusion that when the temperature of a pound of water is increased by one degree of Fahrenheit's scale, an amount of *vis viva* is communicated to it equal to that acquired by a weight of 890 pounds after falling from the altitude of one foot.

The Experiments

ON THE EXISTENCE OF AN EQUIVALENT RELATION BETWEEN HEAT AND THE ORDINARY FORMS OF MECHANICAL POWER. By James P. Joule, Esq. (*In a letter to the Editors of the "Philosophical Magazine"*). *Phil. Mag. Ser. 3, Vol. XXVII.*

Gentlemen:

The principal part of this letter was brought under the notice of the British Association at its last meeting at Cam-

bridge. I have hitherto hesitated to give it further publication, not because I was in any degree doubtful of the conclusions at which I had arrived, but because I intended to make a slight alteration in the apparatus calculated to give still greater precision to the experiments. Being unable, however, just at present to spare the time necessary to fulfill this design, and being at the same time most anxious to convince the scientific world of the truth of the positions I have maintained, I hope you will do me the favour of publishing this letter in your excellent Magazine.

The apparatus exhibited before the Association consisted of a brass paddle-wheel working *horizontally* in a can of water. Motion could be communicated to this paddle by means of weights, pulleys, &c., exactly in the manner described in a previous paper.¹

The paddle moved with great resistance in the can of water, so that the weights (each of four pounds) descended at the slow rate of about one foot per second. The height of the pulleys from the ground was twelve yards, and consequently, when the weights had descended through that distance, they had to be wound up again in order to renew the motion of the paddle. After this operation had been repeated sixteen times, the increase of the temperature of the water was ascertained by means of a very sensible and accurate thermometer.

A series of nine experiments was performed in the above manner, and nine experiments were made in order to eliminate the cooling or heating effects of the atmosphere. After reducing the result to the capacity for heat of a pound of water, it appeared that for each degree of heat evolved by the friction of water a mechanical power equal to that which can raise a weight of 890 pound to the

¹Phil. Mag. ser. 5. vol. xxiii. p. 436. The paddle-wheel used by Rennie in his experiments on the friction of water (*Phil. Trans. 1831, plate xi. fig. 1*) was somewhat similar to mine. I employed, however, a greater number of "floats," and also a corresponding number of stationary floats, in order to prevent the rotatory motion of the water in the can.



JAMES PRESCOTT JOULE
1818-1889

height of one foot had been expended.

The equivalents I have already obtained are:—1st, 823 lb., derived from magneto-electrical experiments; 2nd, 795 lb., deduced from the cold produced by the rarefaction of air; and 3rd, 774 lb., from experiments (hitherto unpublished) on the motion of water through narrow tubes. This last class of experiments being similar to that with the paddle-wheel, we may take the mean of 774 and 890, or 832 lb., as the equivalent derived from the friction of water. In such delicate experiments, where one hardly ever collects more than half a degree of heat, greater accordance of the results with one another than that above exhibited could hardly have been expected. I may therefore conclude that the existence of an equivalent relation between heat and the ordinary forms of mechanical power is proved; and assume 817 lb., the mean of the results of three distinct classes of experiments, as the equivalent, until more accurate experiments shall have been made.

Any of your readers who are so fortunate as to reside amid the romantic scenery of Wales or Scotland could, I doubt not, confirm my experiments by trying the temperature of the water at the top and at the bottom of a cascade. If my views be correct, a fall of 817 feet will of course generate one degree

of heat and the temperature of the river Niagara will be raised about one fifth of a degree by its fall of 160 feet.

Admitting the correctness of the equivalent I have named, it is obvious that the *vis viva* of the particles of a pound of water at (say) 51° is equal to the *vis viva* possessed by a pound of water at 50° plus the *vis viva* which would be acquired by a weight of 817 lb. after falling through the perpendicular height of one foot.

Assuming that the expansion of elastic fluids on the removal of pressure is owing to the centrifugal force of revolving atmospheres of electricity, we can easily estimate the absolute quantity of heat in matter. For in an elastic fluid the pressure will be proportional to the square of the velocity of the revolving atmospheres, and the *vis viva* of the atmospheres will also be proportional to the square of their velocity; consequently the pressure will be proportional to the *vis viva*. Now the ratio of the pressures of elastic fluids at the tem-

peratures 32° and 33° is 480: 481; consequently the zero of temperature must be 480° below the freezing-point of water. We see then what an enormous quantity of *vis viva* exists in matter. A single pound of water at 60° must possess $480^{\circ} + 28^{\circ} = 508^{\circ}$ of heat; in other words, it must possess a *vis viva* equal to that acquired by a weight of 415036 lb. after falling through the perpendicular height of one foot. The velocity with which the atmospheres of electricity must revolve in order to present this enormous amount of *vis viva* must of course be prodigious, and equal probably to the velocity of light in the planetary space, or to that of an electric discharge as determined by the experiments of Wheatstone.

I remain, Gentlemen,

Yours respectfully,

JAMES P. JOULE.

Oak Field, near Manchester,
August 6, 1845.

Science News Letter, January 21, 1933

fibers in the transparent tissues of a frog tadpole's tail. During the past year he has also been studying nerve fiber growth in salamanders, which are rather remote zoological cousins of the frogs. He finds that the growth process in this order of animals is essentially the same as those he observed in the tadpole tails.

Science News Letter, January 21, 1933

PHYSIOLOGY

First Step Taken Toward Synthetic Sex Hormone

THE FIRST STEPS toward making a female sex hormone in the chemical laboratory seem to have been taken by two British investigators, Dr. J. W. Cook of the Cancer Hospital and Dr. E. C. Dodds of the Middlesex Hospital, London.

These two scientists have produced a chemical compound which, when injected into castrated rats, has an appreciable oestrogenic action similar to that of the sex hormone, oestrin. In their report to *Nature*, Drs. Cook and Dodds give the following formula for their compound: one keto, one, two, three, four tetrahydro phenanthrene.

Phenanthrene is a coal tar product used in the artificial production of dyes and drugs. The rest of the new compound's long name tells the chemist the way in which additional hydrogen and oxygen are combined with the phenanthrene.

At least four female sex hormones have been reported in recent years from research centers in the United States, Canada, England and Germany. They have been obtained from human placental material and from the kidney secretions of expectant mothers. These substances appear to be the same chemically, but they differ somewhat in the effects they have on the animal body.

Science News Letter, January 21, 1933

PHYSIOLOGY

Motion Pictures Made of Growing Nerve Fibers

MOTION PICTURES demonstrating how nerve fibers grow through living tissue, and how they repair themselves when injured, have been made by Prof. Carl C. Speidel of the University of Virginia. Prof. Speidel was the winner of the \$1000 prize of the American Association for the Advancement of Science at the midwinter meeting at New Orleans last year. A recent report to the Association summarizes his work up to that time and describes advances made since then.

As pictured and explained by Prof. Speidel, nerve growth is pioneered by what are known as "growth cones" on the ends of the nerve fibers. These are thickenings of the tips, which probe their way through the tissues, constantly sending out and retracting tiny processes from their surfaces, like finger-tips feeling their way. As the nerve progresses, special cells develop along its course. They hug its sides closely, though they take no part in its actual growth process, nor in its function as a nerve. These are known as the "sheath cells." Finally, as the nerve becomes more mature, it develops around itself a layer of fatty material called the "myelin sheath."

All these developments were shown in the motion picture. In life, the growth process is rather slow, but by taking only one picture in two seconds and then projecting them at normal movie speed of sixteen to the second, the apparent rate of growth was speeded up 32 times. Another portion of the film was taken at the rate of one frame in eight seconds, giving them a speeding-up effect on the screen of 128 times the natural rate.

Growth after injury, as well as normal growth, was studied by Prof. Speidel. It has long been a disputed point whether a severed nerve grew together again or started afresh from the cut end nearest the central nervous system. Evidence apparently supporting both views has been produced in the past. Prof. Speidel's studies showed that where the two cut ends apparently grew together again, there was an anastomosis, or anatomical detour, connecting them by another path. A cut end really quite separated from the central nervous system degenerates and disappears, and a new nerve fiber grows out to replace it.

Prof. Speidel's first studies were conducted by watching the growth of nerve

*"... the Lion and the Lizard keep
The Courts where Jamshyd gloried
and drank deep."*

CHARLES DARWIN

—explains in the next Classic of Science the part played by the humble earthworm not only in working over the garden soil but in burying the dead cities of antiquity.
