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Cluster 2

30 July 2014

The mechanical equivalent of heat

The history of heat has been very unstable until the mid 1800's. During this time period, James Joule through his paddle wheel experiment, changes the way heat would be perceived from then on. Joules conducts the experiment and finds the direct relationship between heat and energy such that heat is a form of energy. This new view of heat as energy has paved the way for modern physics and many contributions to society through the new knowledge of heat.

Heat is a concept and term that has been eluding a simple definition for hundred of years. The earliest of all theories about heat was the Phlogiston theory. The theory stated that during the process of burning, that phlogiston is released into the air from a combusted item into a colder body. Similarly the Caloric theory, which followed, embodied the belief that a the caloric of a warm body would flow towards the colder body. The belief of the Caloric theory ran high until the turn of the 19th century where Benjamin Thompson (Count Rumford) disproved the theory with his cannon experiment. He showed how the frictional heat that was produced allowed water to boil in just two hours and thirty minutes while the specific heat of the materials remained the same and that frictional heat from motion was the sole reason for the results attained (2). Rumford showed that the heat involved was related in some manner to the work done on the cannon, but did now obtain the actual relationship (6). With the Caloric model now disproved by Count Rumford, he had also made a major step in setting up the stage for the mechanical equivalent of heat and finding the new definition and way in which we observe heat to be. The next big step in finding the mechanical equivalent of heat came from James Joule himself.

The objective of Joules experiment was to establish a relation between the amount of work spend to the amount of heat released (6). The way in which Joule went about finding this specific relationship was to conduct his famous paddle wheel experiment. The experiment consisted of a brass calorimeter to contain heat and the mass of the water, a watertight lid with a thin layer of leather and white lead. Inside the calorimeter, there are 4 fixed vanes and 8 paddles which are equally spaced between the vanes through the apparatus. The paddles are attached to a spindle which goes through the calorimeter into a drum which has string wound around the part. In addition the drum is attached to a handle with a pin on top which allows for a mechanical cranking of the apparatus. The strings then extends towards both sides where they are wound around a pulley system on both sides of the calorimeter. The stings are attached to two equal four pound weights which are at equal heights (5). The heights of the masses are recorded and measured accurately since there are 2 equal scales on both sides of the apparatus. In addition to the important aspects of the lab is the ever so crucial thermometer with a 95% accuracy measurement, which is attached to the inside of the brass calorimeter. Now that the experiment is set up, the steps taken by Joule was made with extreme accuracy and precision as he was a stickler for accuracy of measurements. He first began with winding the handle of the drum up to a certain height and would then move behind a wooden wall thus protecting the system from excess radiation and any other possible forms of disturbances of heat that could be recorded. Joule, in order to find this relationship, had to take data with respect to a certain height. In order to attain a height of approximately 105.021 feet, Joule repeated his experiment 20 times. In each of these trials of the experiment, Joule had a separate friction and radiation test. The radiation tests that he conduced was significant in the way that he was able to note that there was minimal to no radiation interference with the actual calorimeter to skew the data. The other major part of the experiment was to test and find the actual heat expenditure at the expense of the work exerted on the object. The measurements that Joule took during this portion of the experiment was: the total fall of weights in inches, mean temperature of air, the difference between mean of the final and initial temperature inside the brass calorimeter, and finally a measure go the gain or lass of heat during the whole experiment. In addition to to the calculations from the experiment, James Joule went into the gritty and minuscule values of friction which nonetheless helped the accuracy of the experiment. The frictional values that he attained leeds Joule to be able to calculate accurate vales for thermal capacity of the pieces of the apparatus. Thus, through Joules meticulous probing for an accurate measurement, his work paid off as he attained values such that constitute a relatively accurate measurement of the energy needed to raise water by 1˚F.

The experiment that James Joule is performing with each component labeled on the diagram (3).

The paddle wheel mean experimental data

mean experiments	total fall of weights in in.	mean difference of final and initial temperature	gain or lass of heat during the experiment.
mean friction	1260.248	0.305075˚	0.575250 gain
mean radiation	0	0.322950˚	0.012975 gain

Joules then discovered that the entire capacity of the system was calculated to be =93229.7grs. =7.842299 1˚F lbs. With this measurement the fall along with pressure from the masses account to = 6067.114 ft lbs. So with both numbers we do the calculation of 6067.114/7.842299=773.64 ft lbs. This value of approximately 773.64 ft lbs. is truly amazing as it allows us to derive the all important formula for James Joule: W=JQ (1). With this formula James Joule has completed his desire for the experiment as he has now conclusively established that heat is a form of energy. The results that James Joule himself stated is as follows: 1. That the quantity of heat produced by the friction of bodies whether solid or liquid, is always proportional to the quantity of force expended. 2. That the quantity of heat capable of increasing the temperature of a pound of water by 1˚F requires for the evolution of expenditure of a mechanical force represented by the fall of 772 lbs. through the space of 1 ft. (4).

The consequences of his discovery was that shortly after Joules experiment, the molecular-kinetic theory was elaborated in which heat energy is now based on the chaotic motion of particles in a body. Such a discovery along with the way the change in SI units such that the formula W=JQ can be written now as W=Q, an important formula to understand all types of mechanical and thermal energy. In addition, from this experiment people are now able to view heat as the movement of particles and their interaction with one another and the way in which particles bounce and move randomly. Such an idea from the experiment allows the fields of physics dealing with particle motion and behavior to have a greater understanding of atoms and how atoms have kinetic and potential energy that causes such energetic and hot reactions to take place.

Overall this pivotal experiment by James Prescott Joule has made its impact on history and the way heat is now looked and defined. Heat is now a measurable quantity which is equal to the amount of work done on the body. Heat has its basis in molecular and kinetic theory in which movement and bumping account for heat to be produced. And most importantly heat is a form of energy thus proving that the work of James Joule was a success.

Works Cited

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