The Force of Gravity Creates Energy:
The "Work" of James Prescott Joule

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James Prescott Joule (1818-1889) was the son of a successful British brewer. He tinkered with the tools of his father's trade (particularly thermometers), and despite never earning an undergraduate degree, he was able to answer two rather simple questions:

1. *Why is the temperature of the water at the bottom of a waterfall higher than the temperature at the top?*

2. *Why does an electrical current flowing through a conductor raise the temperature of water?*

In order to adequately investigate these questions on our own, we need to first define "temperature" and "energy." Second, we should determine how the measurement of temperature can relate to "heat" (as energy). Third, we need to find relationships that might exist between temperature and "mechanical" energy and also between temperature and "electrical" energy.

Definitions: Before continuing, please write down what you know about *temperature* and *energy* below. If you require more space, use the back.

<u>Temperature:</u>

<u>Energy:</u>

We have used the concept of gravity to show how acceleration of freely falling objects is related mathematically to distance, time, and speed. We have also used the relationship between net force applied through a distance to define "work" in the Harvard Step Test. Now, through the work of Joule, we can equate the concepts of "work" and "energy":

Energy is the capacity of a physical system to do work.

Potential energy is "stored" energy, kinetic energy is "moving" energy. One type of potential energy is that induced by the gravitational force between two objects held at a distance (there are other types of potential energy, including electrical, magnetic, chemical, nuclear, etc). The equation describing gravitational potential energy is:

$$PE_{gravitational} = m\ g\ h$$

m is the mass (in kg)
g is the acceleration imparted by gravitational force (in m/s^2)
h is the vertical height of the water (in meters)

When the units of these 3 values are applied to the equation, the resulting unit for potential energy is "$kg\ m^2 / s^2$ "

Kinetic energy is less complicated… if a mass is moving, it possesses kinetic energy:

$$KE = \frac{1}{2}\ m\ v^2$$

m is the mass (in kg)
v is the velocity (or speed, in m/s)

When the units of these two values are inserted into the equation, the resulting unit for kinetic energy is also "$kg\ m^2 / s^2$ "

Geoscience Energy Connections:
Joule measured temperatures of water above and below the falling water and found a difference. By making careful measurements, he created an opportunity for this temperature difference to be related to mechanical work. The linking value that allowed this relationship to be revealed is called "specific heat capacity" of the material undergoing the temperature change. For water, Joule determined that approximately 4200 $kg\ m^2/s^2$ of energy would cause 1 kg of water to undergo a temperature change of 1^o C. One *gram* of water would then require 4.2 $kg\ m^2/ s^2$ (now represented as 4.2 *joules*) of energy to experience a 1^o C temperature increase. More careful measurements now indicate that the value of the specific heat capacity of water is 4.184 J/g ^{o}C (the unit can be interpreted as *joules of energy per gram of water per degree Celsius change)*. In equation form, specific heat capacity is given an abbreviation "c":

$$H = m\ c\ \Delta t$$

(for water, **m** is mass in grams, change in temperature (or "**Δt**") is expressed in degrees Celsius, and **c** is 4.184 J/g ^{o}C)

A "*calorie*" of heat has been defined as the amount of heat energy required to change the temperature of 1 gram of water by 1^o C. Therefore, 1 calorie of heat energy is equivalent to 4.184 joules of energy.