Name **Section #**

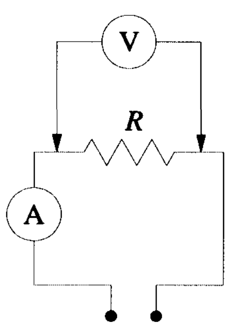
Conversion of Electrical Energy to Heat

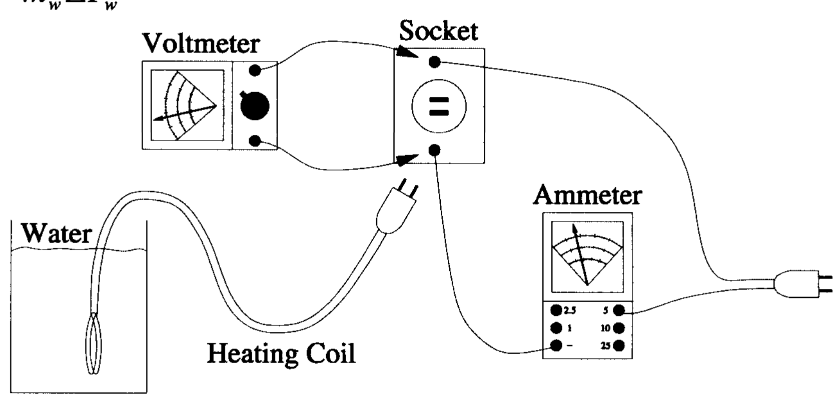
Purpose

In 1843, James Prescott Joule reported the results of his experiment in which a system of descending weights was used to turn paddles immersed in water. He demonstrated that heat was a form of energy by showing that the water gained 1 calorie of heat for every 3.09 foot-pounds of gravitational potential energy lost by the descending weights. Using SI units, this is equivalent to stating the specific heat of water to be: $c_w = 4190 \dfrac{\text{J}}{kg \cdot K}$. You will replicate Joule's experiment and determine c_w by using electrical rather than mechanical energy to heat the water.

Theory

By conservation of energy, the electrical energy dissipated by the heating coil will be the heat gained by the water, or $VIt = c_w m_w \Delta T_w$. For the diagram below: V represents the potential across the coil, I is its current, and t is the time the coil is heating the water. The water's mass and temperature change are given by m_w and ΔT_w, respectively. Rearranging the terms, we obtain for the specific heat of water: $c_w = \dfrac{VIt}{m_w \Delta T_w}$.





Procedure

Measure the mass of a Styrofoam cup that is approximately 80 percent full of cold tap water. (Remember to subtract the mass of the cup.) Record the temperature of the water prior to immersing the heating coil into it. When the coil is already in the water connect it to the socket, allow 300 seconds (5 minutes) to elapse, disconnect the heating coil, and measure the water's final temperature. *Applying power to the heating coil when it is not immersed in water is likely to damage the coil.* Monitor the ammeter and voltmeter while the coil is plugged in. If the readings fluctuate, enter what you believe to be the average readings in the data table on the next page. The thermometer should remain in the cup for the entire time.

Make a small hole in a piece of paper for the thermometer, and use the paper to cover the cup in order to minimize heat transfer between the water and the air.

Repeat the entire procedure three additional times, each time using fresh tap water. Calculate the average of your four experimental values for the specific heat of water and compare it to the accepted value in the second table.

Trial #	1	2	3	4
V (V)				
I (A)				
t (s)				
m_w (kg)				
T_i (C°)				
T_f (C°)				
ΔT (K)				
$c_w \left(\frac{\text{J}}{\text{kg} \cdot \text{K}}\right)$				

Experimental Value (average) c_w	Accepted Value for c_w	Percent Difference
	$4190 \left(\frac{\text{J}}{\text{kg} \cdot \text{K}}\right)$	

Questions

List as many factors as possible that would account for the percent difference between your experimental value and the accepted value of c_w .

Is using a Styrofoam cup, instead of a calorimeter, an important source of error? Justify your answer by discussing the precision of your determination for c_w and the relative masses of the cup and the water.

Questions continued

The lack of precision in your temperature readings and the transfer of energy between the water and its surroundings are probably the two most important sources of error. Which of these was the most serious? Justify your answer by discussing what effect each of these errors would have on your reported value of c_w .

Determine the resistance of the heating coil and calculate the amount of time required to bring 2 kg of water from 15 C to its boiling temperature, if the coil were connected across a 115-volt line.

How much time would be required if the coil were instead connected across a 230-volt line such as is common in Europe?

If 4,190 J of electrical energy are required to raise the temperature of 1 kg water by 1 K, does it necessarily follow that all of this energy could be recovered if the water were to cool down by 1 K? Justify your answer.