EXPERIMENT 2

Electrical Energy

Objectives

1) Calculate the electrical power dissipation in a resistor.
2) Determine the heat added to the water by an immersed heater.
3) Determine if the energy dissipated by the immersion resistor is completely transferred to heat added to the water.
4) Measure the resistance of an immersion heater.

Introduction

When a voltage is applied across a resistor, an electrical current will flow through the resistor. As an electron travels along, it occasionally collides with the ions of the resistor and causes these ions to vibrate with greater amplitude than they had before the collision. In this way, the collisions increase the vibrational amplitude and thus the vibrational energy of the ions. This increase in vibrational energy corresponds to a change in thermal energy (heat). Electrical energy has been converted into heat. This is one example of the conversion of energy from one form to another. In this experiment you will calculate the electrical energy dissipated by the immersed resistor and measure the amount of heat added to the water, then determine if the energy conversion is complete.

The electrical power (P) dissipated by a resistor is given by

$$P = VI$$

where, P (in watts)= power
V (in volts)= voltage
I (in amps)= current

From the power, we can calculate the work done by the resistor, which is given by

$$W = P\Delta t$$

where, W (in joules)= work
P (in watts)= power
Δt (in sec)= time elapsed when the voltage is applied to the resistor

Heat is a form of energy. Traditionally, heat is measured in units of calories (cal) instead of joules. One calorie is defined as the amount of heat necessary to raise the temperature of 1 gram of water by one degree Centigrade (°C). The conversion factor between calories and joules is:

$$1 \text{ cal} = 4.18 \text{ joules}$$

When a resistor is immersed in a cup of water and a current is passed through it, the electrical energy dissipated by the resistor will be converted into heat, and the heat may be absorbed by the water, the cup, the resistor, etc. The amount of heat can be calculated by using the following equation:

$$H = m_w * c_w * \Delta T + S \qquad (1)$$

where, m_w = mass of the water, c_w = specific heat of water
ΔT = increase in temperature in degrees Centrigrade

S represents the heat dissipated in the resistor, the cup, etc. In this experiment, S will be very small compared to $m_w c_w \Delta T$, and will be assumed to be zero (S=0).

Converting the unit from calories to joules, we have

$$H_w = 4.18 * m_w * c_w * \Delta T \text{ (joules)} \qquad (2)$$

where c_w is in units of cal/gm°C.

We will be using deionized water that has been refrigerated to cool it to below room temperature. We will do this to compensate for heat that was transferred to the air in the room from the calorimeter. To do this, we will not start to take data until the water has heated up to about 4° C below room temperature. Then, we will continue to take data until the water as reached about 4° C above room temperature. This way, the heat that was absorbed by the water when it was below room temperature will be offset by the heat that was absorbed by the room when the water was above room temperature. This should help to balance out and eliminate most of the error that was caused by using a calorimeter that is not a perfect insulator.

We assume that energy will be conserved. If this is true, then the energy that was produced by the resistor will all be absorbed by the water. By comparing the energy produced by the resistor and the heat energy gained by the water, we can verify this.

Apparatus

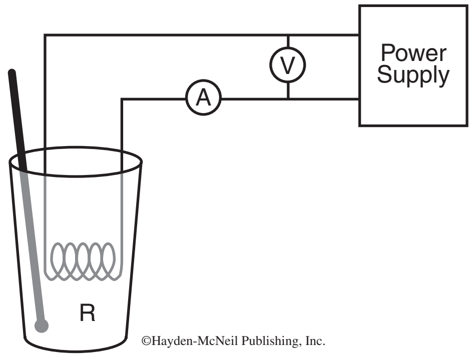

Figure 1

W O R K S H E E T

ELECTRICAL ENERGY

EXPERIMENT 2

Name

Section Number

Date

Procedure

1. Weigh the cup using the scale provided (ask your TA where the scale is located in the room). Using chilled water from the refrigerator, fill your cup with enough water to cover the resistor coil if the lid were on. Now reweigh the cup (now filled with water) and determine the mass of just the water. Record your results below.

Mass of cup	m_c = ___________ ± ___________
Mass of cup and water	m_c+m_w = ___________ ± ___________
Mass of water	m_w = ___________ ± ___________
Room temperature	T_R = ___________ ± ___________

2. Measure the resistance of the coil (R_{coil}) with the digital multimeter, using the Ohm scale. Set the meter back to volts. Place the resistor in the cup. Connect the circuit as shown in figure 1. Turn the current knob (which is just a limit knob) all the way up and adjust the voltage until you have a current of 3 amps. Read and record the **current from the power supply meter**, and measure the **voltage with the digital multimeter** at the output of the power supply (V_{PS}) and at the cup (V_{cup}). Use the voltage at the cup for your calculations.

R_{coil} ___________ ± ___________ V_{PS} = ___________ ± ___________
V_{cup} = ___________ ± ___________

3. Let the resistor heater warm up the water. (One member of the team **must** continuously shake the cup to dissipate the heat uniformly in the water.)

4. When the temperature reaches 4°C below room temperature, record the current (I_{start}) and start watching the clock. Record the temperature in the "electrical_energy" spreadsheet every 30 seconds. Read and record the current from the power supply when the temperature reaches room temperature (this will be I_{room}). Stop recording the temperature when it reaches 4°C above room temperature and turn off the power supply. Read and record the current from the power supply once again (this will be I_{stop}). Remeasure R at that time by disconnecting the resistor from the power supply and using the multimeter on the Ω setting just like you did to get R_{coil} (this will be R_{final}).

   I_{start} = __________ ± __________ I_{room} = __________ ± __________

   I_{stop} = __________ ± __________

   Start time ____ : ____ : ____ End time____ : ____ : ____ R_{final} _____ ± _____

   Record the water temperature every 30 seconds. Use spreadsheet to keep data.

5. Calculate the temperature change (ΔT) and the time span (Δt) from start to stop.

   Δt = __________ ± __________ sec
   ΔT= __________ ± __________ °C

6. Calculate the power dissipated in the resistor, using V_{Cup}, and the associated error using both:

$P=VI$, $\delta P=P\{\delta V/V+\delta I/I\}$ and $P = V^2/R$ $\delta P=P\{2\,\delta V/V+\delta R/R\}$

   Q: Which form gives a more accurate power value? (Fill in that value below) Why did you choose that one?

   P = __________ ± __________ watts

   Q: Were V_{cup} and V_{PS} different? Why? Why use V_{cup}?

7. Determine the work done by the resistor and the associated error

   $W=P\Delta t$ $\delta W = W\{\delta P/P + \delta(\Delta t)/\Delta t\}$

   W = __________ ± __________ joules

Q: Which uncertainty is more important, the uncertainty in time or in power?

Q: Plot Temperature versus time using your data. Was the power constant? Justify your answer.

8. Calculate the heat added to the water using equation (2) and the associated error.

   Specific heat of water C_w = 1.0 cal/gm°C
   $\delta H_w = H_w \{\delta m/m + \delta(\Delta T)/\Delta T\}$

   Show your calculations: H_w = __________ ± __________ joules

9. Compare the work done by the resistor and the heat added to the water. Is energy conserved? (You should take into account the errors.) Was the heat energy found in the water less or more than the electrical energy? (Was energy lost or gained?) Discuss possible sources of apparent energy loss or gain in this experiment and its analysis.

STUDENT NOTES