612-1331 (15-127) Calorimeter Resistor

Introduction

Whenever an electrical current flows in a conductor, some electrical energy is converted into heat energy. For a given current *I*, the energy conversion is greater in a conductor of greater resistance. This is analogous to the conversion of mechanical energy into heat energy due to frictional resistance. The heat generated in an electrical circuit is commonly referred to as *joule heat***,** after **James Prescott Joule** (1818 - 1889), the English scientist who investigated the conversion of electrical energy to heat (and also the mechanical equivalent of heat.)

Materials Needed:

- **15-120 Aneroid Calorimeter**
- **15-127 Calorimeter Resistor**
- **Power supply or 6v battery**
  Can use 10-171 Battery Kit from **Science First**
- **Ammeter (0 to 3A)**
- **Voltmeter, 20v**
- **Connecting wires**
- **Thermometer**
- **Stopwatch or laboratory timer**
- **Laboratory balance**

Theory

Power *P* expended in an electrical circuit is given by:

$$P = VI \qquad (1)$$

where *V* = voltage
I = current

By integrating (adding up) power over time *t*, we get work, *W*, done by the circuit.

$$W = Pt \qquad (2)$$

or

$$W = VIt$$

By Ohm's Law,

$$V = IR \qquad (3)$$

we get:

$$W = I^2Rt = \frac{V^2t}{R} \qquad (4)$$

where **R** is the resistance of the circuit in ohms.

The electrical energy expended is manifested as heat energy and is called **joule heat** or I^2R losses, with I^2R being the power or energy expended per time.

Equation 4 shows how the joule heat varies with resistance:

> 1. For a constant current *I*, the joule heat is proportional to resistance: I^2R
> 2. For a constant voltage *V*, the joule heat is inversely proportional to the resistance, V^2/R.

The energy expended in an electrical circuit as given by *Equation 4* is in the units of joules. The relationship (conversion factor) between joules and heat units in calories was established by James Joule from mechanical considerations - the *mechanical equivalent of heat.* In Joule's mechanical experiment, a descending weight turned a paddle wheel in a liquid. He then correlated the mechanical (gravitational) potential energy lost by the descending weight to the heat generated in the liquid. The result was **1 cal = 4.186 J.**

A similar electrical experiment may be done to determine the "electrical equivalent of heat." By the conservation of energy, the heat equivalents of mechanical and electrical energy are the same (i.e. 1 cal = 4.186 J.)

Experimentally, the amount of electrical joule heat generated in a circuit element of resistance *R* is measured by calorimetry methods. If a current is passed through a resistance in a calorimeter in an arrangement as shown in *Diagram 1*, by the conservation of energy, the electrical energy expended in the resistance is equal to the heat energy (joule heat) *Q* gained by the system:

Electrical energy expended = heat gained

$$W = Q$$

or

$$IVt = (m_{cal}c_{cal} + m_{coil}c_{res})(T_f - T_i)$$

where the *m's* and *c's* are the masses and specific heats of the calorimeter, and resistor, respectively, as shown by the subscripts. T_f and T_i are the final and initial temperatures of the system, respectively.

Procedure

1 Weigh calorimeter to nearest gram or use value of 485 g if no balance is available. The mass of the resistor is so small it can be ignored.

2. Place the resistor in the calorimeter and set up the circuit as shown in *Diagram 1.*

3. After the circuit has been checked, plug in the power supply and set to 6v. Disconnect power supply. This procedure should be done as quickly as possible to avoid heating the calorimeter.

4. Record initial temperature T_i.. Then re-connect the power supply with connecting wires. At the same time, start the stopwatch or laboratory timer. Start at even minutes if a clock is used. Read and record the initial ammeter and voltmeter readings after 30 seconds. Record the voltage and the current at one minute intervals..

5. When the temperature of the calorimeter is 10 to 15° C above the initial temperature, simultaneously disconnect the power supply and stop the timer at the time of a particular minute interval reading. Keep recording termperature until a maximum temperature is reached and record this temperature *(T_f).*

Procedure

1 Weigh calorimeter to nearest gram or use value of 485 g if no balance is available. The mass of the resistor is so small it can be ignored.

6. Compute the electrical energy expended in the coil (in joules) from the electrical and time readings by using *Table 1.*

7. (a) Compute the heat energy (in calories) gained by the calorimeter system by using formula **$(T_F - T_I)$ MC**
where M = mass of calorimeter
C = specific heat of calorimeter
(which is 0.210 cal/g° C, equal to that of aluminum.)

(b) Taking the ratio of the electrical and heat energy results, find the "electrical equivalent of heat." Compare this to the value of the mechanical equivalent of heat by computing the percent error.

8. Repeat the experiment and use the average value of the experimental results in determining the percent error.

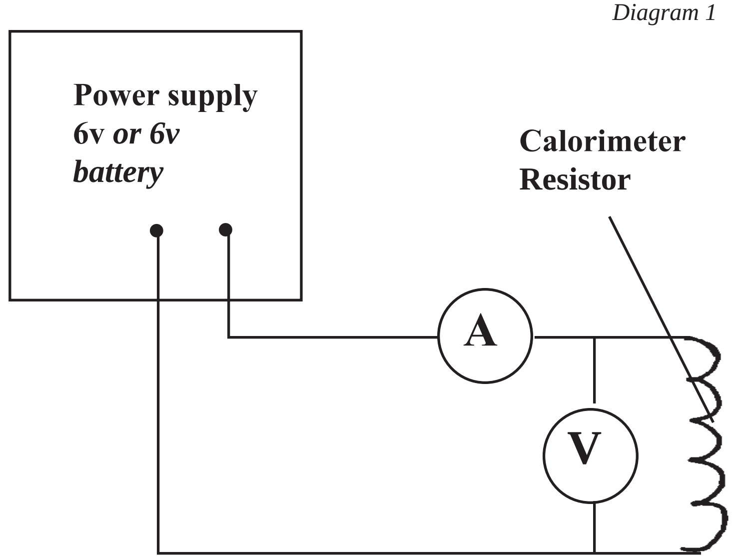

Diagram 1

Table 1.

Minutes Interval	Voltage V	Amperage A	Joules V * A * 60
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
		Total Joules	

Related Products

The following products may be ordered from your distributor or, if unavailable, from manufacturer **Science First®.**

612-1330 Aneroid Calorimeter - 5 times more senstivie than traditional versions, needs no water. Die-cut styrofoam insulation assures accurate results.

612-1332 Specific Heat Specimens - Five specimens representing major groups of the Periodic Talbe. 15-060 (constant volume) is made to fit inside 15-120 calorimeter core.

615-4065 Battery Kit - Build a safe, low voltage power supply from 1 1/2 to 6 volts. You need 4 D batteries.

612-0035 Precision Linear Expansion Apparatus - Determine coefficient of expansion of iron, copper, brass, aluminum with included metal rods. Warm tap water is all that is needed. Fully assembled with attached (inches reading) Dial Indicator.

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