Experiment 12. Joule's Constant

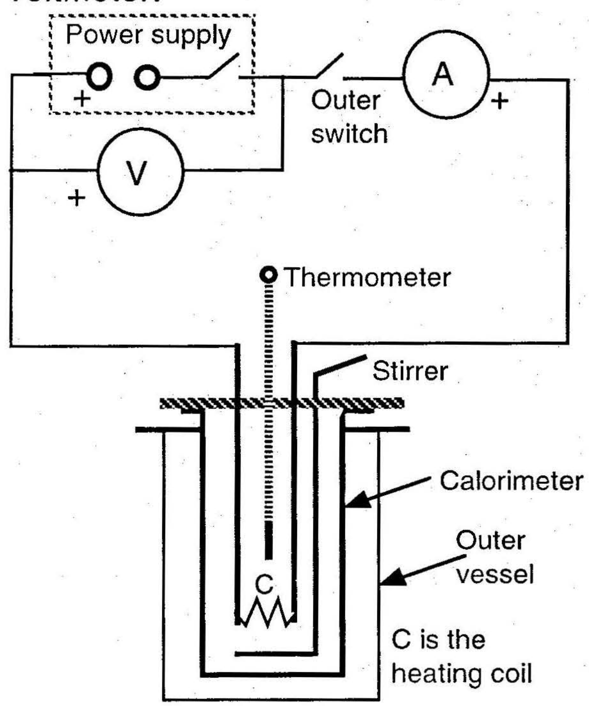
Joule, while on his honeymoon, found that the water at the bottom of a fall is warmer than the water at the top of the fall, and established the equivalence between mechanical work and heat.

Objective:

To determine Joule's constant (J) or the mechanical equivalent of heat by electrical method.

Apparatus:

An electrical calorimeter, a thermometer, a balance, a power supply, an ammeter and a voltmeter.



Schematic Diagram of Electrical Calorimeter

Theory:

According to the first law of thermodynamics, the amount of work converted into heat (W) is directly proportional to the quantity of heat generated (H).

Thus $W = J H$,

where J is called the mechanical equivalent of heat or Joule's constant.

Therefore, $J = W/H$.

If W is measured in joules and H is measured in calories, the unit of J will be joule/calorie.

In this experiment, electrical energy (W) is converted into heat. If a voltage V (in volts) is applied across a resistor and thus a current I (in amperes) is maintained for a time t (in seconds), the electric power is given by

$P = V\ I,$

and the electrical energy converted into heat is given by

$W = V\ I\ t.$

The electrical energy supplied to the heating coil is converted into heat. This heat is taken up by the calorimeter (including the stirrer, heating coil, etc.) and the water in the calorimeter. If the temperature of the system rises from T_1 °C to T_2 °C, the heat generated is given by

$H = (m_1 s + m_2 + m_3)(T_2 - T_1),$

where m_1 = mass of the calorimeter,

s = specific heat capacity of the calorimeter,

m_2 = mass of water in the calorimeter,

m_3 = water equivalent of the heating coil, stirrer, etc. (that is, the mass of water whose heat capacity is equal to the heat capacity of the heating coil, stirrer, etc.)

Procedure:

1. Make the electrical connections as shown in the schematic diagram of the electrical calorimeter. Keep the outer switch open.
2. Find the least counts of the voltmeter, ammeter and thermometer. Read the room temperature. Record specific heat capacity [s = 0.22 calories/(gm C°)] of the calorimeter and the water equivalent of the heating coil, stirrer, etc. [m_3 = 2.5 gm].
3. Weigh the empty dry calorimeter correct up to 0.1 gm.
4. Mix some hot and cold water such that the temperature in the calorimeter is about 3 °C below the room temperature. Fill the calorimeter about 2/3 with water. Wipe any drops of water sticking to the sides of the calorimeter.
5. Weigh the calorimeter plus water correct up to 0.1 gm.
6. Wind the timer and set it to zero. Keeping the outer switch off, switch on the power supply. Adjust the voltage to a bit less than 6 volts. (Use the 6-volt range.)

7. Read the temperature of water in the calorimeter correct up to the least count of the thermometer. This is the temperature at time zero and it is also the initial temperature of the system (T_1).
8. Close the outer switch and simultaneously start the timer. Read the voltmeter and ammeter. Enter these in the first row of the table on the data sheet.
9. Take the readings of the voltage, current and temperature at regular intervals of 2 (or 3) minutes. Keep stirring the water in the calorimeter carefully.
10. Switch off the current at the end of N intervals of time. The number N should be chosen such that the final temperature is about as many degrees above the room temperature as the initial temperature was below. For example, if the room temperature was 26 ^{o}C and the initial temperature T_1 = 23 ^{o}C, then the final temperature should be about 29 ^{o}C.
11. Keep stirring and record the highest temperature attained by the system. This is the final temperature T_2.
12. Perform the calculations and repeat the experiment if the result does not have the desired accuracy.

Note that if the voltage V is in volts and current I is in amperes, then the power P (=V I) will be in watts, and the energy W (= V I t) will be in joules.

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York College of The City University of New York

Physics I

Name:

Experiment No. 12: Pre-Lab Questionnaire

Complete the following data sheet:

Specific heat of the material of the calorimeter, $s = 0.093$ cal/(gm.C^o)

Water equivalent of the heating coil, stirrer, etc., $m_3 = 6.8$ gm

Mass of the empty dry calorimeter, $m_1 = 123.4$ gm

Mass of calorimeter plus water, $m = 280.1$ gm

Mass of water in the calorimeter, $m_2 =$

No.	Time (min)	Temperature (C^o)	Voltage (V)	Current (A)	Power (watt)
1	0	22.6	5.2	1.1	
2	3	24.1	5.1	1.1	
3	6	25.4	5.2	1.2	
4	9	26.8	5.0	1.0	
5	12	27.8	5.2	1.1	

Interval No.	Time interval (min)	Average Power (watt)
1	0 - 3	
2	3 -6	
3	6 - 9	
4	9 -12	

Length of a time interval, $t =$

Total average power, $P =$

Total electrical energy supplied, $W =$

Initial temperature, $T_1 = 22.6$ ^oC

Final temperature, $T_2 = 28.2$ ^oC

Amount of heat generated in calories, $H =$

Joule's constant, $J =$

Percent error in $J =$

Experiment No. 12

Name: Marks:

Partner: Remarks:

Section:

Date Submitted:

Title:

Objective:

Theory/Formulas:

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Data Sheet

Least count of the voltmeter =

Least count of the ammeter =

Least count of the thermometer =

Room temperature =

Specific heat of the material of the calorimeter =

Water equivalent of the heating coil, stirrer, etc., m_3 =

Mass of empty dry calorimeter, m_1 =

Mass of calorimeter and water, m =

Mass of water in the calorimeter, m_2 =

Initial temperature of water in the calorimeter, T_1 =

Readings for determining the total electrical power:

Take the readings at intervals of 2 or 3 minutes.

Start reckoning time from the time the current is switched on.

Keep stirring the water in the calorimeter carefully.

The first reading is taken at time t = 0.

Switch off the current at the end of the time interval when the final temperature is nearly as many degrees above the room temperature as the initial temperature was below.

No.	Time (min)	Temperature (C^o)	Voltage (V)	Current (A)	Power (watt)

On switching off the current, continue stirring the water in the calorimeter and record the highest temperature attained. This is the final temperature.

Final temperature of water in the calorimeter, T_2 =

Calculations:

Calculation of total electrical power:

Interval No.	Time interval (min)	Average Power (watt)
1		
2		
3		
4		
5		
6		
7		
8		
9		

Total power (sum of the last column of the above table), P =

Length of each time interval in seconds, Δt =

Total energy in joules, $W = P\ \Delta t$ =

Total heat generated, $H = (m_1 s + m_2 + m_3)(T_2 - T_1)$ =

$J = W/H$

Percent error in the experimental value of J =

Experiment No. 12: Questions

1. What is meant by J?

2. Why should the final temperature be approximately as many degrees above the room temperature as the initial temperature was below?

3. What is the purpose of measuring the voltage and current at regular intervals during the course of the experiment? Briefly explain the method of determining W.