The Sixth Experiment

THE RELATION BETWEEN HEAT AND ELECTRICAL ENERGY (JOULE EQUIVALENT)

The Objective of the experiment:

To understand the equivalence of electrical energy and heat energy, and how to measure electrical energy, and finally to measure the Joule equivalent of electrical energy.

The Used Equipments:

- DC Power supply.
- Ammeter with a measuring range (2-3) amps.
- Voltmeter with measuring range (10) volts.
- Rheostat.
- Copper calorimeter with its outer cover.
- Thermometer.
- Stop watch.
- Electrical source.

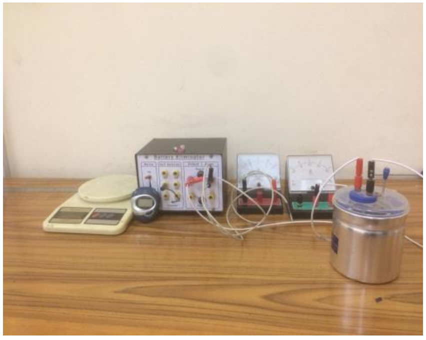

Figure (1)

The Theoretical Part:

The theory for electrical energy and power was developed using the principles of mechanical energy, and the units of energy are the same for both electrical and mechanical energy. However, heat energy is typically measured in quantities that are separately defined from the laws of mechanics and electricity and magnetism. Sir James Joule first studied the equivalence of these two forms of energy and found that there was a constant of proportionality between them and this constant is therefore referred to as the Joule equivalent of heat and given the symbol J. The Joule equivalent of heat is the amount of mechanical or electrical energy contained in a unit of heat energy. The factor is to be determined in this experiment.

If a current of (I) ampere passes for a period of time (t) seconds through the resistance of the potential difference between its ends (V) volts, then the energy (W) expended in the resistance, measured in joules, is equal to:

$W=V\,I\,t$………(1)

This energy can be used to raise the temperature of the calorimeter and the liquid contained in it from the initial temperature (θ_1) to the final temperature (θ_2), and in case that no energy is lost, then the amount of electrical energy passing through the wire is equal to the amount of absorbed thermal energy by the calorimeter and its contents, if the units of electrical energy are in joules and thermal energy in calories, then the relationship between electrical work (W) and heat (H) is given by the following equation:

$W = J\,H$……….(2)   where J is joule equivalent

Since the heat energy gained by a calorimeter of mass (m_0) and specific heat (c_0) and contains a mass of water (m) and specific heat (c), then:

$V\,I\,t = J\,(m_0c_o + mc)(\theta_1+\theta_2)$ ………(3)

Because part of the energy is lost by radiation, equation (3) requires correction based on Newton's law of cooling, which states "the time rate of cooling is proportional to the difference in two temperatures", meaning the last rate multiplied by (t/2).

Therefore, if the calorimeter and its contents were left to cool from (θ_2) with a time (t/2), then the real temperature of the group should become (θ_3), then ($\theta_2+ \theta_3$) would be the amount of temperature loss, and thus (θ_2) becomes the actual temperature according to the following equation:

$\theta_2 =\theta_2+(\theta_2-\theta_3)$

Thus, equation 3 can be written as

$V\,I\,t = J[m_0\,C_0 +(m_1 -m_0\,)\,C\,][\,\theta_2 + (\theta_2 - \theta_3) - \theta_1]$……….(4)
Where ($m_1 -m_0$) represents the mass of water (m)

The Procedure:

1. Clean the calorimeter and record its mass while it is empty, let it be (m_0) in gram.
2. Put an appropriate amount of water so that the heating coil is immersed and record its mass with the calorimeter, let it be m_1 in gram.
3. Calculate the mass of water $m= (m_1 -m_0)$ in gram.

4. Record the temperature of the calorimeter with water which represents the initial temperature θ_1 in Celsius.
5. Let the current pass in the coil after the circuit is closed and start heating the water and the calorimeter (the current must remain constant throughout the experiment), and let it be I = 2 amp.
6. Record the temperature of the calorimeter with water every minute until there is a noticeable change in the temperature of the water (that is when the temperature becomes ten degrees greater than the initial temperature θ_1, and it is represented by θ_2 at which the heating coil was extracted of the calorimeter, record the time (t) it took to heat up from (θ_1) to (θ_2).
7. Continue recording temperatures during cooling approximately every two minutes until the temperature of the group drops about two degrees Celsius from (θ_2).
8. Arrange the results as in the table below:

The heating

t(min)	1	2	3	4	5	6	7	8	9	10
θ(Celsius)										

m_0: the mass of the calorimeter as it is empty in gram.
m_1: the mass of the calorimeter with water in gram.
m= ($m_1 - m_0$) the mass of water in gram.
c : the specific heat of water is equal to 1 Cal/gram °C
c_0: the specific heat of calorimeter is equal to 0.22 Cal/gram °C
I: in ampere
V: in volts

The cooling

t(min)	2	4	6	8	10
θ(Celsius)					

9. Plot a figure between t(min) on x-axis and θ(Celsius) on y-axis and find the values of θ_1, θ_2, θ_3.
10. Calculate Joule equivalent using equation (4) as explained before.