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# Comparison of Newton Correction Between Joule's Law Experiment and Ice Heat of Fusion Experiment

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**ABSTRACT**
The reliability of the thermophysical experiment results is largely determined by the accuracy of temperature determination. The arising problem is that the measured temperature does not indicate the temperature that corresponds to the thermal process of the system, because it is already affected by environmental temperatures that are different from the system temperature. The temperature of the object which is measured by the thermometer is the one that has been affected by the ambient temperature. While the one used to calculate the heat is the temperature of the object that is not affected by the ambient temperature. In this case, it is necessary to take into account the temperature correction that follows Newton's Law for cooling or heating rate for calculating the heat. This research aimed to compare the results of Newton Correction applications on two experiments using calorimeters. One is the experiment of converting electrical energy into heat, popularly known as the Joule's Law experiment. The second experiment was an energy conservation experiment to determine the ice melting heat (heat of fusion) based on Black's principle, by mixing water with ice. In Joule's Law experiment, heat generated from the conversion of electrical energy was used to raise the temperature of the calorimeter and its contents. This meant that the ambient temperature was always smaller than the temperature of the calorimeter. While on the experiment of determining the melting heat of ice, the temperature of the calorimeter and its contents will decrease, then the ambient temperature is always greater than the temperature of the calorimeter. Newton's correction comparison in the two experiments was evaluated through constant comparison of Newton's law formulation for cooling or heating rates. The results showed that there was a better result both in Joule's Law experiment and the Heat of Ice Fusion experiment if Newton Correction is applied without Newton Correction. The value of constant of Newton Correction was obtained in both experiments is in the same order.

***Keywords:*** *Newton correction, environmental temperature influence, Joule's Law, the heat of fusion of ice.*

## 1. INTRODUCTION

The practice of physics in the laboratory is a learning tool to improve the skills of the scientific process. One of the scientific processes that is quite important and is expected to be achieved through practical activities is the suitability between empirical facts and theoretical concepts. Often practical activities do not support theoretical concepts because of various factors that result in deviations between the results of experiments and theoretical concepts. One of the contributing factors is the unfulfillment of ideal conditions that correspond to the theoretical assumptions of the experiment. Such conditions are related to the measurement of various physical quantities, one of which is temperature measurement [1].

The reliability of the thermophysical experiment results is largely determined by the accuracy of temperature determination. The arising problem is that the measured temperature does not indicate the temperature that corresponds to the thermal process of the system, because it is already affected by environmental temperatures that are different from the system temperature. When determining the magnitude of thermal quantities such as the heat generated in a calorimeter, it is necessary to calculate the difference in the temperature of the object. The temperature difference of the object is not just a measurable temperature change, because the temperature of the object is different from the ambient temperature. Measured temperature does not automatically state the physical temperature of the calorimeter, because the measured temperature is the result of the calorimeter temperature and the influence of cooling or heating rate by the environment which temperature is lower or higher than the calorimeter temperature. Therefore, it is necessary to correct the temperature of the calorimeter.

The temperature of the object measured by the thermometer is the one that has been affected by the ambient temperature. While the one used to calculate the heat is that is not affected by the ambient temperature. In this case, it is necessary to consider the temperature correction that follows Newton's Law for cooling or heating rate for calculating the heat. Newton's correction is a way to correct the influence of ambient temperature on an object's temperature when the temperature of an object is greater or smaller than the ambient temperature [2][3][4][5].

The formulation of the dependence of the object's temperature on time due to the influence of higher or lower ambient temperatures than the temperature of objects follows Newton's correction which has been previously studied [2][3]. In the formulation of Newton's correction, there is a proportional constant (k) between the rate of temperature change to the difference between the ambient temperature (L) and the system temperature (T):

$$\frac{dT}{dt} = k(L - T) \tag{1}$$

This constant value *k* can be calculated from the temperature observation data against the time when the energy conversion has ended and then applied to the data when the energy conversion occurs to determine the temperature correction [6][7].

Some physical quantities which are stating the thermal behavior of materials have no constant value. The value depends on the thermal process. For example, the specific heat of a solid depends on temperature. The molar specific heats of most solids at room temperature and above are nearly constant, in agreement with the Law of Dulong and Petit. At lower temperatures, the specific heats drop as quantum processes become significant. The low-temperature behavior is described by the Einstein-Debye model of specific heat [1]. In this study, the behavior of Newton's correction k will be examined in the cooling process and the heating process due to the influence of ambient temperature. So this study will answer the question of whether Newton's Correction Formula [2] is generally accepted or specifically applied to a certain condition.

## 2. OBJECTIVE AND METHODOLOGY

This research aimed to compare the results of Newton Correction applications on two experiments using calorimeters. One was the experiment of converting electrical energy into heat, popularly known as the Joule's Law experiment. The second experiment was an energy conservation experiment to determine the ice melting heat (heat of fusion) based on Black's principle, by mixing water with ice. Both experiments used the same calorimeter, as well as media (in this case, water, which we have already known its specific heat) which also has the same mass. The methods used were experimental methods, including the determination of the heat capacity of the calorimeter [8], the Joule's Law experiment, and the ice melting heat experiment [9]. This research hypothesizes that there is no significant difference in Newton's correction constants between cooling and heating conditions even though the temperature changes are opposite. It means that the way to calculate that constant of Newton's correction is the same for the cooling process as well as for heating process. All experiments were conducted at the Applied Physics Laboratory of Politeknik Negeri Bandung.

## 3. RESULT AND DISCUSSION

Equation 1 can be solved into :

$$\boldsymbol{T = L - A.exp(-k\,t)} \tag{2}$$

for ambient temperature (L) higher than system temperature (T), and

$$\boldsymbol{T = L + A.exp(-k\,t)} \tag{3}$$

for ambient temperature (L) less than system temperature (T).

A is a constant, which can be eliminated from two pairs of temperature and time measurements. From that measurement, the constant k can be calculated as :

$$k = \frac{\ln\left[\frac{T_1 - L}{T_2 - L}\right]}{t} \tag{4}$$

with $L$ stating ambient temperature, $T_1$ and $T_2$ respectively represent temperatures under two different conditions with a time interval of *t*.

Joule's Law experiment was conducted by flowing an electric current through a resistive coil that was put into the water in a container called a calorimeter.

The quantities measured during the flow of an electric current are the electric current (i), the potential difference between the ends of the coil (V), the mass of water (m), the heating time (t), and the temperature of the water (T). The measurement of electrical energy can also be done at once with the provision of voltage through the joulemeter device, which directly shows energy measurement. The temperature measurements are carried out in a certain time interval since the current is streamed to a certain time after the current is stopped. The amount of electrical energy given to the coil is :

$$W = V\ i\ t \tag{5}$$

In accordance with the statement of Joule's Law, the electrical energy is converted into heat (Q), thus:

$$Q = W \tag{6}$$

Heat generated through the coil is used to raise the temperature of the system, namely water and calorimeter, so that the temperature will rise, with the relationship:

$$Q = (C_D + m\ c\ )\ (\Delta\ T\ ) \tag{7}$$

with c stating specific heat of water, and $C_D$ is heat capacity of the calorimeter.

Experimentally, the magnitude of the temperature increase equals the difference between the final temperature of the calorimeter after the electric current is stopped ($T_A$) and the initial calorimeter temperature at the time the electric current begins to flow ($T_o$).

$$\Delta T = T_A - T_0 \tag{8}$$

It is obvious that the accuracy of this experiment's result depends on the accuracy of final temperature ($T_A$), which should be corrected by Newton's correction.

In ice melting heat experiments, ice (solid form of water) with a mass of $m_E$, which is assumed to be at a melting temperature of $0^oC$ (pressure 70 $cm_{Hg}$) is mixed with liquid water with mass m and temperature $T_o$. After all the ice melts into water, the system temperature becomes $T_A$, and in observation, this temperature is the lowest temperature during the experimental process. The heat released by water and calorimeter is

$$Q_{release} = m\ c\ (T_0 - T_A) + C_D\ (T_0 - T_A) \tag{9}$$

The heat received by ice is :

$$Q_{received} = m_E\ M + m_E\ c\ T_A \tag{10}$$

which M is stating heat of ice fusion.

If the equations 9 and 10 are equated, then the heat of the melting ice is equated to :

$$M = \{(mc + C_D\ )\ (T_0 - T_A)/m_E\ \} - cT_A \tag{11}$$

Again, the accuracy of this experiment result depends on the accuracy of $T_A$, which should be corrected by Newton's correction.

In the Joule's Law experiment, heat generated from the conversion of electrical energy was used to raise the temperature of the calorimeter and its contents, and this meant that the ambient temperature was always smaller than the temperature of the calorimeter. While on the experiment of determining the melting heat of ice, ice in the calorimeter absorbs the heat. So, the temperature of the calorimeter and its contents will decrease, then the ambient temperature is always greater than the temperature of the calorimeter. These phenomena are visualized by figures 1 and 2 below.

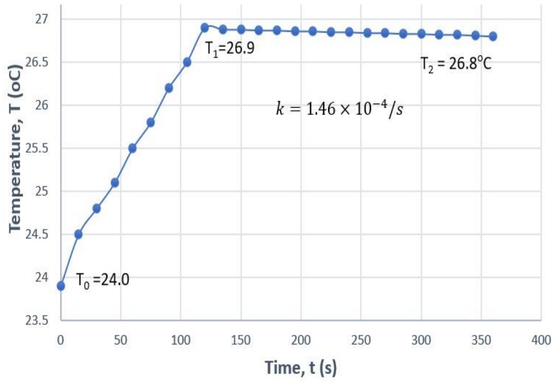


**Figure 1** The graph between temperature (T) against time (t), Joule's Law Experiment. Source: Data Processing

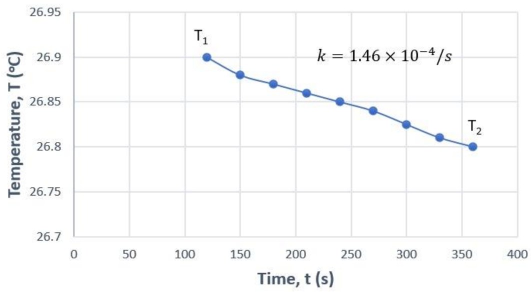


**Figure 2** The graph between temperature (T) against time (t), Joule's Law Experiment, after current stopped. Source: Data Processing

Explanation of Joule's Law Experiment data is visualized in Figure 1 and Figure 2. Electric current is flowing during the time from 0 until 120 seconds. During that time, electrical energy is converted into heat energy and showed by rising in temperature. At t = 120 s, the current is stopped, so now there is no more electrical energy converted into heat. Theoretically, the temperature should be constant after that. However, experimentally, it can be seen that the temperature is decreasing as time goes by. This fact shows the influence of ambient temperature, which is lower than the system. From this condition, without energy addition from current, Newton's correction constant k can be calculated according to equation 4. After that, a calculated value of k is applied to correct final temperature during energy conversion (from $T_A$ become $T_{AK}$) by the relation :

$$T_{AK} = T_0 + (T_A - T_0)e^{-kt} \tag{12}$$

Joule's Law experiment aimed to prove experimentally the law of energy conservation by calculating the ratio of Q and W, from equations 5 and 7. Theoretically, this ratio should equal 1. Without Newton's correction, results obtained for this ratio is 0,914; and with the application of Newton's correction, results obtained 0,932.

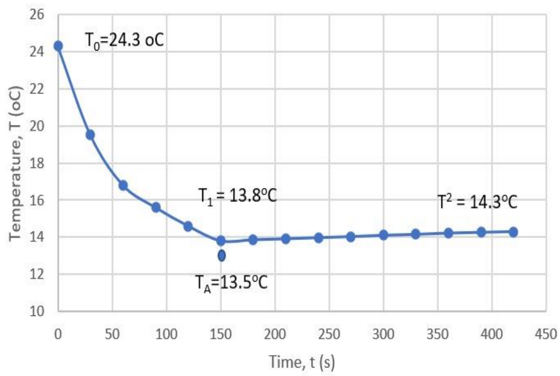


**Figure 3** The graph between temperature (T) against time (t), Ice Fusion Heat Experiment. Source: Data Processing

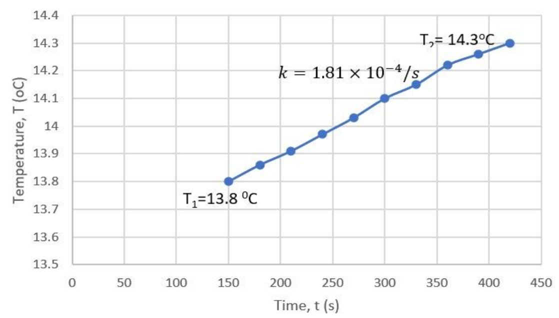


**Figure 4** The graph between temperature (T) against time (t), Ice Fusion Heat Experiment, after ice melting. Source: Data Processing

Explanation of Ice Heat of Fusion Experiment data visualized in Figures 3 and 4 is as follows. Liquid water and solid ice are mixing, starting at time t = 0. From t =0 until t = 150 s, ice is melting, and the process ends at t = 150 s. During that process, the temperature of the system is reducing until the lowest value. This lowest value of temperature is the final temperature of the melting process. Theoretically, the temperature should be constant after that. However, experimentally, it can be seen that the temperature is rising as time goes by. This fact shows the influence of ambient temperature, which is higher than the system. From this condition, after the final temperature of ice melting, Newton's correction constant k can be calculated according to equation 4. After that, the calculated value of k is applied to correct final temperature during ice melting (from $T_A$ become $T_{AK}$) by the relation:

$$T_{AK} = T_0 - (T_0 - T_A)e^{kt} \tag{13}$$

The value of Ice Heat of Fusion from this experiment has a deviation of 2,5 % from the real value and with the application of Newton's Correction, the deviation is 0,3 %.

Application of Newton's correction due to the influence of environmental cooling on the Joule's Law Experiment makes the Q/W ratio closer to its true value. Application of Newton's Correction due to the influence of heating by the environment on the Ice Melting Heat Experiment makes the Fusion Heat value obtained closer to the actual value. Thus, it is proven that the application of Newton's Correction makes the results of the experiment better, both in the cooling and heating process.

The value of Newton's correction constant (k) in both experiments is calculated in the same way, i.e. from the observation of temperature to time after the main experimental process is completed using equation 4. What is meant by the main process is the flow of electric current in the Joule experiment, as well as the process of melting ice in the Ice Fusion Heat experiment. The value of constant k obtained in both experiments is in the same order, which is $10^{-4}$ /s. Note that the ambient temperature in both experiments is the same, which is 24 °C. The difference in the front digit of the constant obtained may be due to differences in the rise and fall in temperature (ΔT), as well as the mass of water used in both experiments.

The difference in Newton's correction treatment in both experiments is precisely in its application, which is when Newton's correction is used to correct the final temperature, and this can be seen in the difference in equation 12 and equation 13. Equation 12 with negative-rank exponent features is used for environmental temperatures which are lower than system temperatures. Equation 13 with positive-rank exponent features is used for environmental temperatures which are higher than system temperatures.

## 4. CONCLUSION

Due to the difference between the system and ambient temperature, it is necessary to consider the temperature correction that follows Newton's Law for cooling or heating rate. The application of Newton Correction makes the results of the experiment better, both in the cooling and heating process by ambient temperature.

The calculation of the Newton Correction Constant shows that this constant is in the same order both for Joule's Law Experiment as well as the Heat of Ice Fusion Heat Experiment.

The results showed that there was no significant difference in thermal behavior as well as the way to find Newton's correction constants at cooling rates by ambient temperature (Joule's Law experiment) and Newton's correction constants at the rate of heating by ambient temperature (Heat of Ice Fusion experiment). The difference arises sequentially in the use of negative and positive powers of the exponent of temperature correction formulation related to the process of cooling and heating by the environment.

## ACKNOWLEDGMENT

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