Experiment 8: Thermoelectric Effects

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Abstract

The Findings for this experiment produced a linear curve showing the linear increase of voltage proportional to the increase in temperature demonstrating the Seebeck effect, with a Seebeck coefficient of 11.274. The Peltier Effect was shown as the rate of heat flow was increased non-linearly with the module current for empirical data and decreased for the coefficient of performance.

1 Introduction

In this experiment, the Seebeck and Peltier effects are tested. The Seebeck effect shows that there is a difference in voltage that varies linearly with a difference in temperature. Assuming a temperature gradient in a conductor, the charges will travel from hot to cold, which will produce an emf that is proportional to the difference in temperature given by equation 1. The difference in temperature can be created experimentally by using two conductors joined together with one having the ability to be variably heated while the other stays at a cool constant temperature. The Peltier effect creates a temperature difference from a difference in voltage applied and the rate of heat flow will be proportional to the current as shown in equation 3. The current through the conductors can cause this difference, and it can also reverse the flow by reversing the direction of the current.

1.1 Equations

$$V_1 = S_1 \Delta T \tag{1}$$

$$\Delta V = S_{12} \Delta T \tag{2}$$

$$H = \frac{dQ}{dt} = \pi_{12} I \tag{3}$$

$$H = S_{12}T_cI_m - \frac{1}{2}I_m^2R_m + \frac{T_c - T_h}{R_{th}} \tag{4}$$

$$R_{th} = \frac{T_c - T_h}{P} \tag{5}$$

$$C.O.P = \frac{H}{I_mV_m} \tag{6}$$

1.2 sample calculations

$$\begin{aligned} R_{th} = \frac{T_c - T_h}{P} \\ &= \frac{64.9 - 9.8^oC}{18V} \\ &= 3.06\Omega \end{aligned} \tag{7}$$

$$\begin{aligned} H = S_{12}T_cI_m - \frac{1}{2}I_m^2R_m + \frac{T_c - T_h}{R_{th}} \\ &= (11.274)(282.95K)(1.15A) - 0.5 * (1.15A^2) * 0.23 \\ &= 3668.323W \end{aligned} \tag{8}$$

$$\begin{aligned} C.O.P = \frac{H}{I_mV_m} \\ &= \frac{0.5525W}{(1.15A)(0.489V)} \\ &= 0.982 \end{aligned} \tag{9}$$

2 Experimental Procedure

The experiment tests the two effects separately, the steps followed are noted below.

A point by point procedure can be outlined via:

1. The first effect to be tested was the Seebeck effect. This required the use of a power supply, ammeter, a cold block and a heat sink. Resistors were attached to the sides of the cold block to provide heat. The temperature of the heat sink was to remain constant using the flow of tap water through the heat sink at all times.

2. Approximately 20 Watts of power was dissipated through the resistors, and with the temperature of the heat sink remaining constant, the voltage was recorded for every 4 degrees Celsius increase of the cold block. This produced the data that was plotted in figure 1, the slope of which is the Seebeck coefficient S_{12}.

3. After a while the module reached thermal equilibrium and The thermal resistance was determined using equation 5.

4. The Peltier effect was to be tested next. In this part of the experiment the setup consisted of the same heat sink and cold block with the ammeter and resistors. The power supply was connected to the variac for control of the temperature on the cold block. The objective was to get $T_c = T_h$ by adjusting the variac for different increments of power supplied.

5. First, the power was adjusted to be 2W controlling the voltage and current. This produced a difference in temperatures in the cold block and heat sink, with the temperature of the cold block being higher than the heat sink.

6. The variac was then adjusted until the temperature of the cold block was equal to the temperature of the heat sink. A little wait time for the temperature of the cold block to rise or drop was needed to increase accuracy. The current and voltage at which equilibrium was reached was recorded. Then the same process was repeated for power increments of 4, 6, 8, and 10 Watts of power supplied.

7. Graphs of the empirical and theoretical H were plotted as a function of module current. The coefficient of performance was calculated for each measurement.

3 Results and Tables

The final results for the Seebeck effect were a Seebeck coefficient of 11.274 from a linear trend produced by the experimental data. The empirical and theoretical graphs of heat flow as shown in figures 2 and 3 look like they produced a non-linear and a linear curve, respectively. Finally, the coefficient of performance graphs for empirical and theoretical values in the Peltier experiment are shown in figures 4 and 5, respectively. The curves for both of these graphs are non-linear. The values for these graphs are shown below the curves.

Table 1: Experimental data corresponding to Seebeck effect

V [mV]	T_c, [Celsius]
111.5	20 ± 0.01
157.9	24 $\pm$0.1
197.2	28 $\pm$0.1
239	32 $\pm$0.1
292.9	36 $\pm$0.1
336.7	40 $\pm$0.1
376	44 $\pm$0.1
425	48 $\pm$0.1
474	52 $\pm$0.1
518	56 $\pm$0.1
558	60 $\pm$0.1
606	64 $\pm$0.1
616	64.9 $\pm$0.1

Table 2: Experimental data corresponding to Peltier effect

$Powersupplied$ [W]	$ModuleCurrent$, [Amps]	$Voltmeterreading$ [V]
2	1.1$\pm$0.1	-0.425 $\pm$0.1
4	1.5 $\pm$0.1	-0.615 $\pm$0.1
6	1.75 $\pm$0.1	-0.818 $\pm$0.1
8	2 $\pm$0.1	-1.07 $\pm$0.1
10	2.25 $\pm$0.1	-1.27 $\pm$0.1

4 Graphs

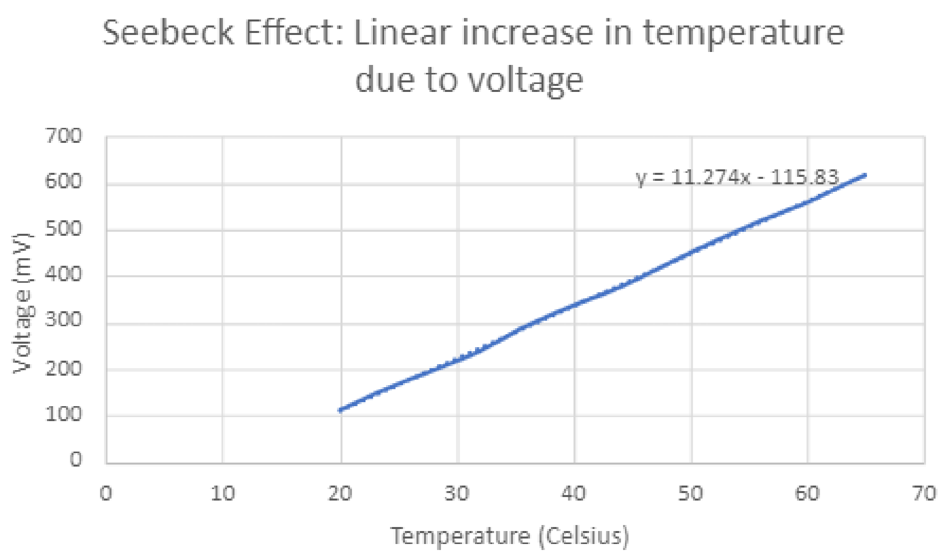

Figure 1: The increase in temperature produces an increase in voltage which is linear.

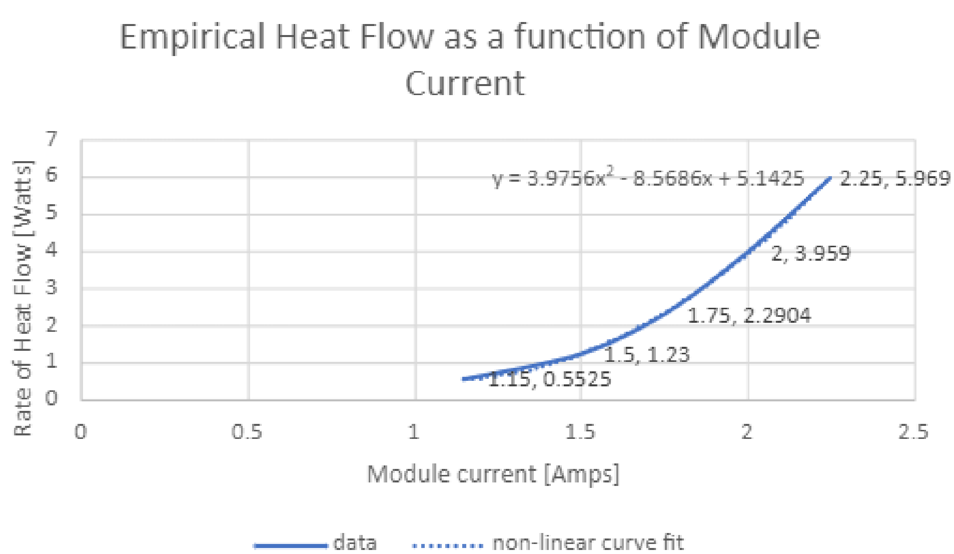

Figure 2: non-linear curve of the rate of heat flow as a function of module current

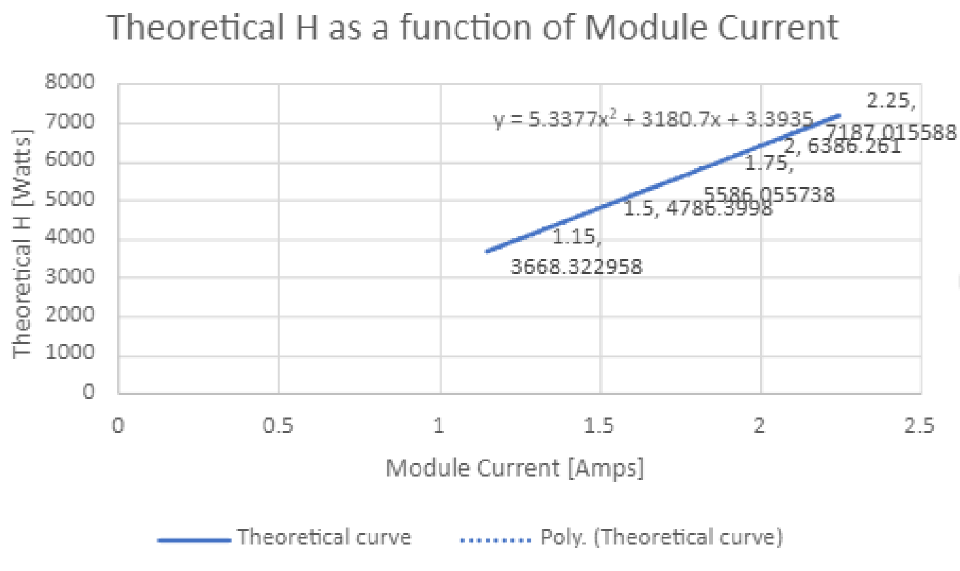

Figure 3: Curve of the theoretical rate of heat flow (equation 3) as a function of module current

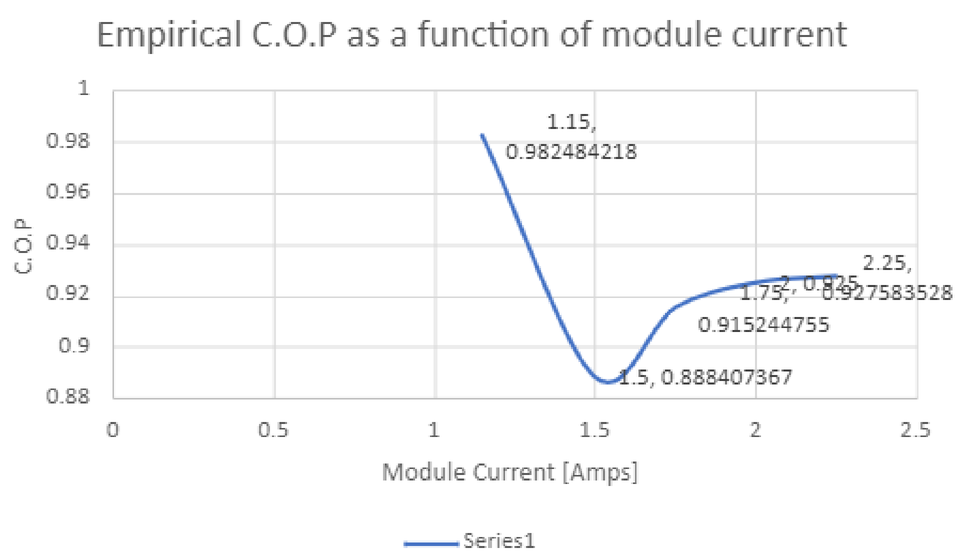

Figure 4: Coefficient of performance (empirical) as a function of module current creates a non-linear curve

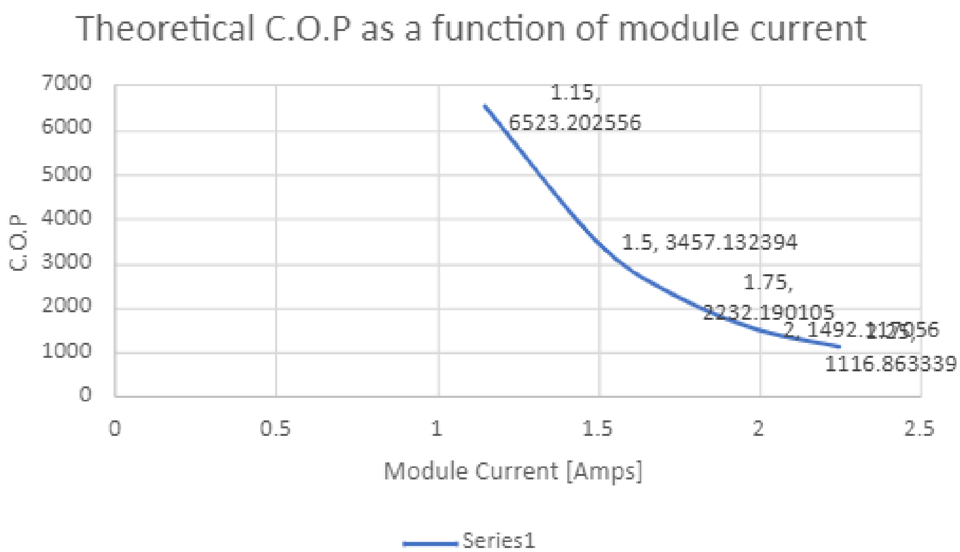

Figure 5: Coefficient of performance (Theoretical) as a function of module current creates a non-linear curve

5 Discussion

The results for the Seebeck effect are as expected and a linear curve demonstrates that the voltage in linearly proportional to the temperature. The Peltier experiment found the curve for empirical rate of heat flow as a function of module current to be non-linear as expected, but the theoretical version of H, calculated from equation 4, to appear linear. This result is not what is expected.

The module should be in thermal equilibrium before recording the data when testing the Peltier effect since we want to find the accurate voltage that produced the equilibrium. The empirical and theoretical curves for the C.O.P produced two non-linear graphs as shown in figures 4 and 5, respectively. This curves for this graph seem to be similar, however the values for the C.O.P are not the same. This difference seems to be the result of some sort of error, which is difficult to detect as the values used for the calculation seem to be accurate. In the empirical graph the C.O.P seems to decrease non-linearly with the module current and then increases and stabilizes. In the theoretical C.O.P graph there is a linear decrease of C.O.P with an increase in module current. This suggests that the performance decreases with more current eventually reaching zero or a plateau.

5.1 Questions

Equation 4 has three terms which can be studied. The first term involves the Seebeck coefficient and is significant as it shows that power increases linearly with the increase in temperature and module current. The second term is negative and it shows the power being taken away by the module due to the current being reversed. The third term is concerned with the power at equilibrium temperature, in our case this term is zero since the cold block and the heat sink temperatures will be equal.

Thermal resistance and electrical can be compared since they are proportional to a difference in temperature and a difference in voltage. As we saw in this experiment, the changes in temperature can cause changes in voltage, and vise-versa. This can be applied to materials as well, if a material is more thermally conductive then it'll likely be more electrically conductive. Metals are a good example of this, as they are good thermal and electrical conductors.

6 Conclusion

The experimental findings for the Seebeck effect were accurate to an expected linear curve. The empirical curve for the rate of heat flow as a function of module current was non-linear as expected as well. The theoretical curve for H, seemed to produce a linear graph, with different values for the heat flow, which is unexpected.

References

[1] Physics 317, Laboratory Manual. University of Victoria, 2019.