Introduction to Sustainable Energy Technologies (SEE605A)

Experiment

On

Basic electronics measurement – 2 (SEEBECK AND PELTIER EFFECT)

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What is Seebeck and Peltier Effect?

The Seebeck Effect and the Peltier Effect are the two major principles that govern the working of thermoelectric generators.

The Seebeck Effect and the Peltier Effect can both be classified under the term **thermoelectric effect**. Any thermoelectric effect involves the conversion of differences in temperatures into voltage differences. The Seebeck and Peltier Effects are different manifestations of the same physical process. In some instances, they are linked and known as the **Seebeck-Peltier Effect**. The reason why these two effects are separated is due to their independent discoveries by two different individuals. Let's first look at what the Seebeck Effect is in detail.

What is Seebeck Effect?

The Seebeck Effect was discovered by the Baltic German physicist Thomas Johann Seebeck. The Seebeck Effect is a phenomenon in which a temperature difference between two dissimilar electric conductors or semiconductors produces a voltage difference between those two substances. When heat is applied to one of the two conductors or semiconductors, the electrons become excited due to the heat. Since only one of the two sides is heated, the electrons start moving toward the cooler side of the two conductors. If both of the conductors are connected in the form of a circuit, a direct current flows through the circuit (see Figure 1).

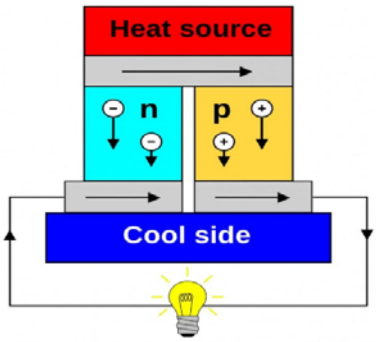


Figure 1. Demonstration of Seebeck Effect

The voltages produced by the Seebeck Effect are tiny. The range of the voltage produced is usually on the order of a few microvolts (one-millionth of a volt) per Kelvin of temperature difference at the junction. If the temperature difference is significant enough, some devices can go on to produce a few millivolts (which is one-thousandth of a volt).

The Seebeck coefficient α (also known as thermopower, thermoelectric power, and thermoelectric sensitivity) of a material is a measure of the magnitude of an induced thermoelectric voltage (V) in response to a temperature difference (ΔT) across that material, as induced by the Seebeck effect.

$$V = \alpha \Delta T \qquad (1)$$

The SI unit of the Seebeck coefficient is volts per kelvin (V/K), although it is more often given in microvolts per kelvin (μV/K). Some materials with their Seebeck coefficient values are shown in the table given below:

Material	Seebeck Coeff.	Material	Seebeck Coeff.	Material	Seebeck Coeff.
Aluminum	3.5	Gold	6.5	Rhodium	6.0
Antimony	47	Iron	19	Selenium	900
Bismuth	-72	Lead	4.0	Silicon	440
Cadmium	7.5	Mercury	0.60	Silver	6.5
Carbon	3.0	Nichrome	25	Sodium	-2.0
Constantan	-35	Nickel	-15	Tantalum	4.5
Copper	6.5	Platinum	0	Tellurium	500
Germanium	300	Potassium	-9.0	Tungsten	7.5

The Seebeck coefficient depends upon:

- Work functions of the metals in the circuit
- Electron densities
- Scattering mechanism

Thermoelectric materials enable the conversion of heat to electrical energy. The performance of electronic thermoelectric materials is typically evaluated using a figure of merit (ZT)

$$ZT = \alpha^2 \rho^{-1} \kappa^{-1} T \qquad (2)$$

where ρ is the electrical resistivity, α is Seebeck coefficient, and κ is the thermal conductivity.

What is Peltier Effect?

The Peltier Effect was named after the French physicist Jean Charles Athanase Peltier, who discovered this phenomenon in 1834. The Peltier Effect is the presence of heating or cooling at an electrified junction of two different conductors. When a current is made to flow through a junction between two conductors, heat may be added or removed at the junction.

The Peltier effect is the opposite of the thermoelectric phenomenon of the Seebeck effect. In this case, when electric current flow within the closed-circuit, one junction of two dissimilar metals absorbs thermal energy in one junction and discharges the same energy at another junction.

On application of a voltage between the terminals T1 and T2 as depicted in Figure 2, an electrical current (I) flows in the circuit. As a result of current flows, a slight cooling effect takes place at junction Q_C and a slight heating effect occurs at junction Qh. The reverse process happens by changing the direction of the current flow.

If Qc is the rate of cooling in watts, and Qh is the rate of heating in watts, I is the current flowing through the closed circuit. The rate of cooling

$$\mathbf{Qc = \beta \times I} \qquad \mathbf{(3)}$$

Where, β is the differential Peltier coefficient between the two materials A and B in volts.

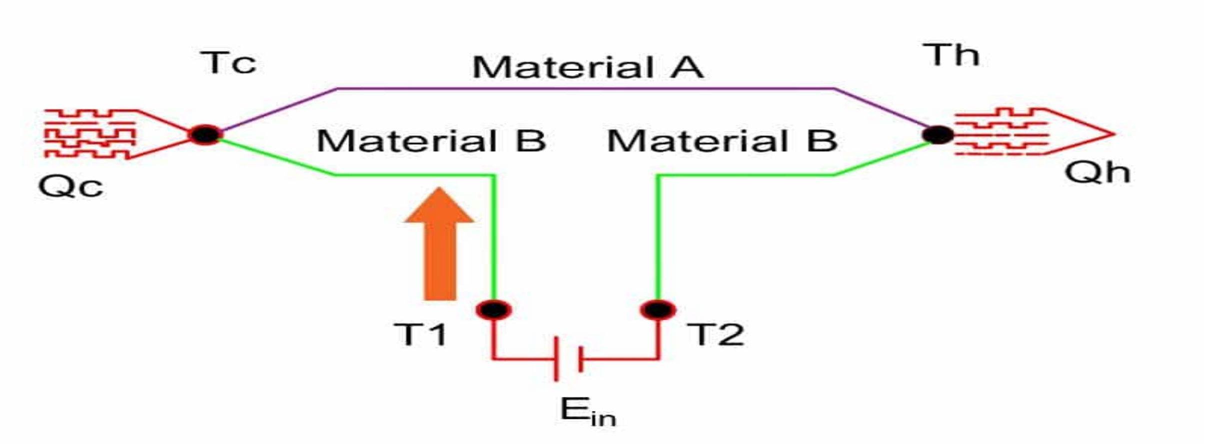


Figure 2. Demonstration of Peltier Effect

<u>Applications:</u> The Peltier cells find their wide application in consumer electronics such as computers, compact refrigerators, and satellites.

Technical Specifications:

The Seebeck Trainer kit has the following components:

S.No.	Component	Specifications	
1	Power Supply	12 V, 20 Amp. SMPS	
2	Peltier Module	Model	TEC1-12710
		Maximum Voltage	15 V
		Operating Voltage	12 V
		Maximum Operating Current	10 A
		Maximum Power	120 W
		Internal Resistance	1.2 to 1.5 ohms
		Dimensions	40*40*3.6 mm
3	Heat Sinks	Small Heat Sink with Fan for Cooler Side Big Heat Sink with Fan for Hotter Side	
4	Temperature Sensor	RTD Type, Pt-100 with temperature range 0-200 deg. C	
5	Temperature Indicator	0-200 deg. C	
6	Voltmeter	0-2 V	

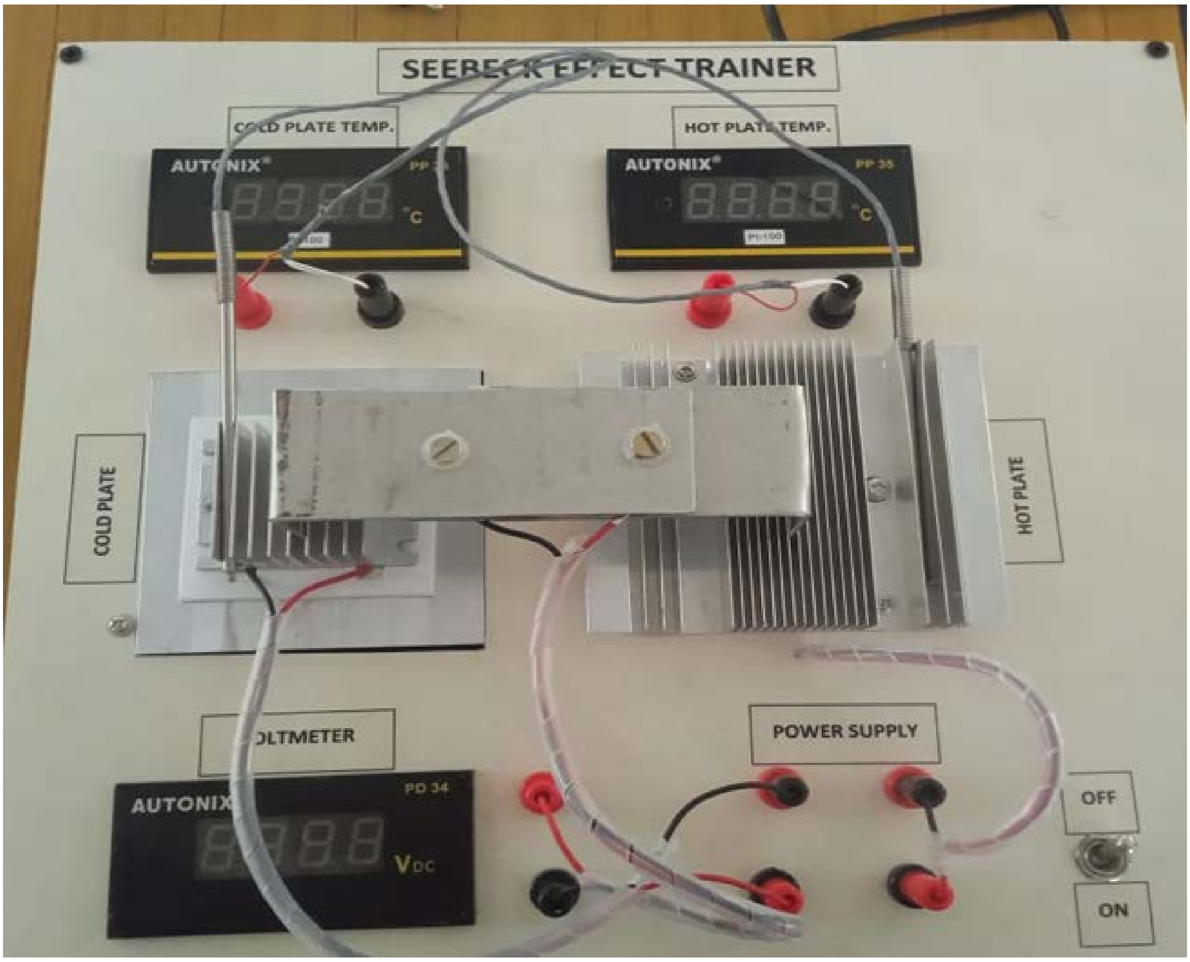


Figure 3. Seebeck and Peltier Kit Setup

EXPERIMENT 1:

Objective: Demonstration of Peltier Effect

Steps for Peltier Effect

a) Connect the Seebeck kit to AC Power Supply

b) Connect the Peltier Modules indicated as Hot Plate and Cold Plate with DC Power supply (12V).

c) Connect Temperature sensors to temperature indicators.

d) Place the temperature sensors on the heat sinks of the Peltier Module indicated as Hot Plate and Cold Plate.

e) Switch on the toggle switch.

Experiment A:

f) When the positive terminal (Peltier) is connected to the positive terminal (power supply) and the negative terminal (Peltier) is connected to the negative terminal (power supply), the surface with the smaller heat sink becomes cold and the surface with the bigger heat sink becomes hot. The "Hot Plate" becomes hotter (temperature starts increasing) and "Cold Plate" becomes cooler (temperature starts decreasing).

g) The temperatures can be seen on the temperature indicator.

S.No.	Cold Plate Temp. (deg. C)	Hot Plate Temp. (deg. C)	Temp. Difference (ΔT)	Time (sec)
1				
2				
3				
4				
5				
6				
7				

8				
9				
10				

Experiment B:

h) When the positive terminal (Peltier) is connected to the negative terminal (power supply) and the negative terminal (Peltier) is connected to the positive terminal (power supply), the surface with smaller heat sink become hot and the surface with bigger heat sink become cold. “Hot Plate” becomes cooler (temperature starts decreasing) and “Cold Plate” becomes hotter (temperature starts increasing).

i) The temperatures can be seen on the temperature indicator.

S.No.	Cold Plate Temp. (deg. C)	Hot Plate Temp. (deg. C)	Temp. Difference (ΔT)	Time(T) (sec)
1				
2				
3				
4				
5				
6				
7				
8				
9				

Results and analysis

Q-1 Plot the curve between the time vs temperature difference for both exp A and exp B.

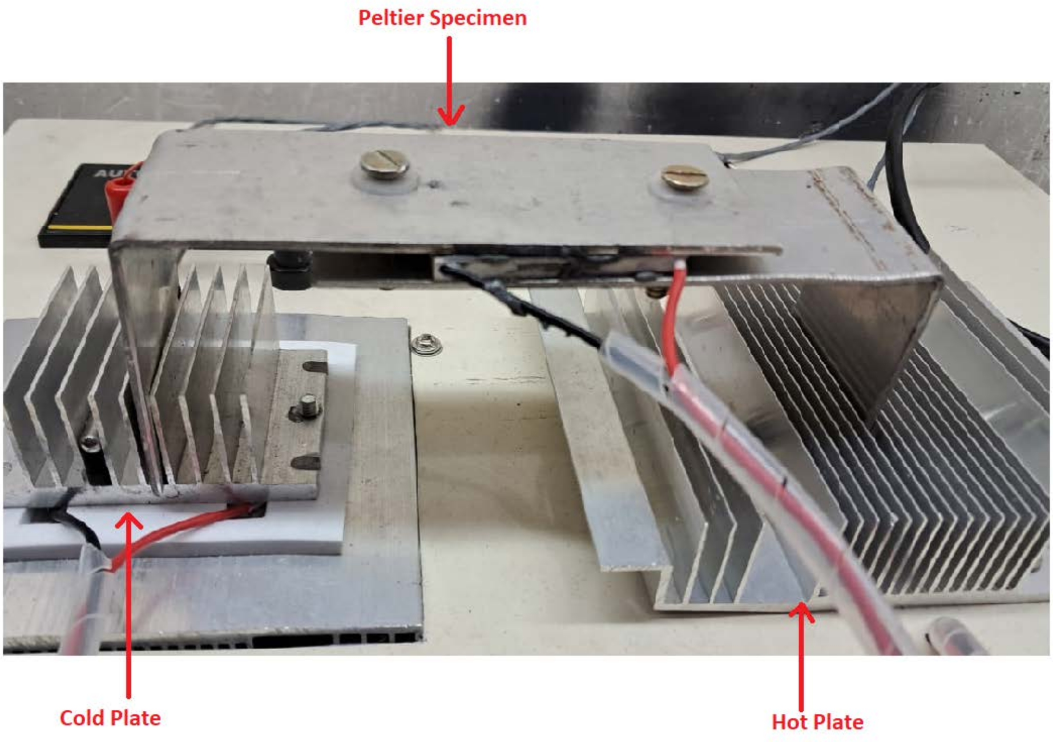
Q-2 Is there any difference in the curve? Comment.

EXPERIMENT:2

Objective: Demostration of Seebeck Effect and determination of Seebeck Coefficient and Figure of Merit

Steps for Seebeck Effect

a) Connect the Seebeck kit to AC Power Supply
b) Connect the Peltier Modules indicated as Hot Plate and Cold Plate with DC Power supply (12V).
c) Connect Temperature sensors to temperature indicators.
d) Place the temperature sensors on the heat sinks of Peltier Module indicated as Hot Plate and Cold Plate.
e) Place the Peltier Specimen with metal conductors on the cold plate and hot plate as one leg is inserted between the cold plate heat sink and the other leg is inserted between hot plate heat sink as indicated in fig.



f) Connect the specimen terminals to Voltmeter.
g) Switch on the toggle switch
h) Collect the readings as follows:

S.No.	Time (sec)	Cold Plate Temp. (deg. C)	Hot Plate Temp. (deg. C)	Temp. Difference (ΔT)	Voltage(V) (sec)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Results and Analysis

Q-1 Plot the curve between voltage and temperature difference and find out the value of Seebeck coefficient.

Q-2 Find Figure of Merit for thermoelectric material and compare it with commercially available material.