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Employment of Human-Emitted Heat for Hand Lamps

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Abstract: The present work concerns the design, manufacturing and testing of a non-battery hand lamp. The present idea is based on utilization of human-emitted heat to activate a Peltier thermo-electric module for electricity generation. This technique is an emerging energy-harvesting application. The size of the lamp is suitable to be hold by the hand of a grown-up person. A group of nine suitable and powerful *LED*s were used as the light source of the lamp. A special housing was designed and fabricated of Teflon. Also, the lamp was supplied by a heat sink to increase the efficiency of the Peltier module. Interesting conclusions and suggestions for further development are stated.

Keywords: Human-Emitted Heat, Hand Lamps, Peltier Thermo-Electric Module

1. Introduction

1.1. Importance

In many actual cases, electricity is not available to provide light. These cases include military operations, long off-road trips, mountain climbing and mining labor. Also, there are situations when utility power is off, for considerably a long period of time, due to natural disasters such as storms, floods, earthquakes, volcanic activities, *etc*.

Chargeable batteries may become empty after a certain period of time without electric supply for recharging. In such situations, non-battery lamp emerges as an excellent solution. The key of the whole idea is to supply the lamp with enough power from sustainable sources.

1.2. Idea

The basic idea of the present work is to utilize a sustainable and accessible energy source to provide hand lamps with the necessary power. It is some sort of non-battery lamps. The design should be simple, reliable and depend on a renewable energy source. Also, the new hand lamp is supposed to be easy to manufacture and competitively cheap.

That is why the employment of human-emitted heat for powering the hand lamps becomes an acceptable and reasonable idea.

There are many advantages in using non-battery lamp, namely: (*i*) Utilization of a renewable (sustainable) energy source, which is human-emitted heat in the present case. (*ii*) Typically effective when battery is not available and/or electricity is shutting-down. (*iii*) Environmentally-friendly device. (*iv*) No waste of chemical materials. Table 1 gives a comparison between battery and non-battery lamps.

Table 1. *Comparison between battery and non-battery lamps.*

No.	Battery Lamp	Non-Battery lamp
1	Less economical	More economical
2	Short time-life	Long time-life
3	Not available at all times	Available all the time
4	No need for heat source	Need for heat source
5	Weather condition is not important	Being more effective in cold weather

Thus, the present work is based on utilizing the emitted heat from human hand to generate electricity from a Peltier thermo-electric module. Then, the electric current is supplied to a group of *LED*s in front of a specifically-designed hand lamb. Details of the present idea will be illustrated in the coming sections.

1.3. Background

The Peltier effect is the presence of heat at an electrified junction of two different metals and is named for French physicist Jean-Charles Peltier, who discovered it in 1834. When a current is made to flow through a junction composed of materials *A* and *B*, heat is generated at the upper junction at T_2, and absorbed at the lower junction at T_1, Figure 1. The Peltier heat absorbed by the lower junction per unit time is equal to

$$Q = \Pi_{AB} I = (\Pi_B - \Pi_A) I \quad (1)$$

Where, Π_{AB} is the Peltier coefficient for the thermocouple composed of materials *A* and *B*, Π_A (Π_B) is the Peltier coefficient of material *A* (*B*), and *I* is the current. Π varies with the material temperature and its specific composition: *P*-type silicon typically has a positive Peltier coefficient below ~550 *K*, but *N*-type silicon is typically negative. The Peltier coefficients represent how much heat current is carried per unit charge through a given material. Since charge current must be continuous across a junction, the associated heat flow will develop a discontinuity if Π_A and Π_B are different. Depending on the magnitude of the current, heat must accumulate or deplete at the junction due to a non-zero divergence there caused by the carriers attempting to return to the equilibrium that existed before the current was applied by transferring energy from one connector to another. Individual couples can be connected in series to enhance the effect. Thermoelectric heat pumps exploit this phenomenon, as do thermoelectric cooling devices found in refrigerators [1].

More details about the Peltier and other thermo-electric modules can be found in Refs. [2-6].

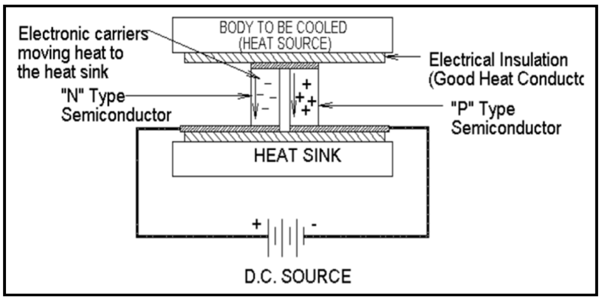


Figure 1. *Schematic drawing of the Peltier thermo-electric module [1].*

Actually, most of the investigators considered the Peltier thermo-electric module for cooling/heating processes. However, some of them were interested in the electricity generation of the Peltier modules. Such researches concerned an apparatus for cooling circuits [7], electrical generators in the classroom [8], *LED* lighting assembly [9], one-dimensional analysis of thermoelectric modules (*TEM*s) [10], powering autonomous sensors [11], multiphysics simulation of thermoelectric systems [12], thermo-electric materials [13] and regeneration of energy [14] in vehicles, and experimental investigation of the performance of a thermoelectric generators [15, 16].

2. Parts of the Present Model

The present model of the hand lamp is shown in Figure 2. Its main components are: (*i*) Peltier thermo-electric module, (*ii*) Electronic chip, (*iii*) Heat sink (copper), (*iv*) Housing (Teflon). The following sections describe the different parts of the model.

Figure 2. *General view of the present hand lamp.*

2.1. Ready-Made Parts

2.1.1. Peltier Thermo-Electric Module

The Peltier thermo-electric module that was used in the present model is shown in Figure 3. Also, its technical details are illustrated in table 2. Its type is TEC1-12706.

In the present work, the Peltier thermo-electric module was used as source of *DC* current by applying a temperature difference between the two surfaces of the Peltier module. The upper surface is heated by human hand; whereas, the lower surface is cooled by heat sink.

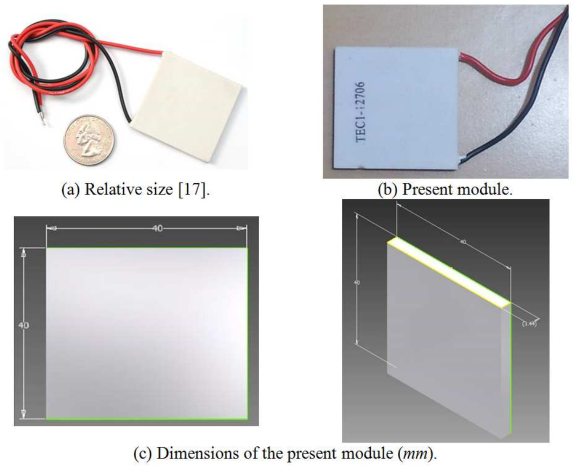


Figure 3. *Peltier thermo-electric module.*

Table 2. *Technical details of the present Peltier thermo-electric module [17].*

Item	Value
Max current	6*A* @ 12*V*
Suggested voltage range	12*V* to 15.5*V*
Maximum temperature differential (T_{max} @ $Qc = 0$)	66°*C*
Maximum cooling power (Qc_{max}) @ 15.3*V*	97*W*
Peltier elements	127

Item	Value
DC resistance	2.5 *ohms*
Seal	Silicone
Dimensions	40×40×3.5 *mm* (1.57"×1.57"×0.13")
Wire length	339.72 *mm* (13.32")
Weight	20.68 *g*

2.1.2. Electronic Chip

This electronic ship, Figure 4, was provided with the Peltier thermo-electric module. It regulates the output current of the Peltier module. The *LED* of the electronic chip was replaced by a number of *LED*s that are more suitable for the present hand lamp model.

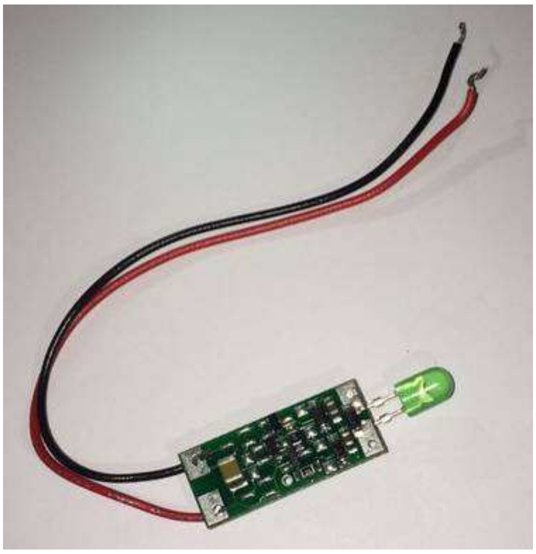


Figure 4. *Present Electronic chip.*

2.1.3. Bolts

A number of three bolts, Figure 5, were used in the present model. Each bolt has a diameter of 4 *mm* and length of 25 *mm*. They were used to assemble the two parts of the body of the hand lamp. Moreover, they ensure the perfect contact between the lower surface of the Peltier thermo-electric module and the copper heat sink. The distribution of the three bolts is shown in Figure 6.

Figure 5. *The used bolts.*

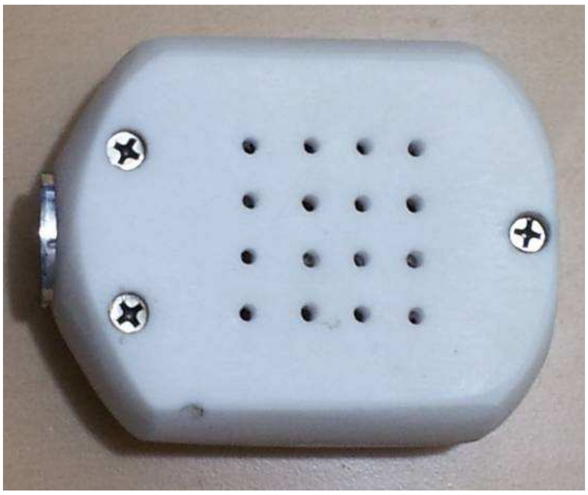


Figure 6. *Distribution of the three bolts.*

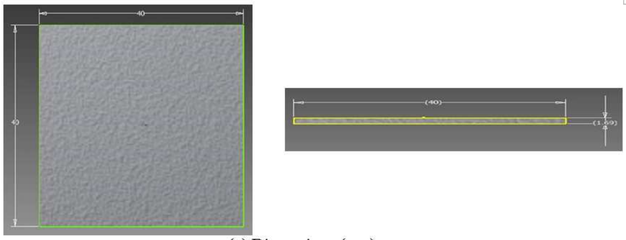
2.2. Manufactured Parts

2.2.1. Heat Sink

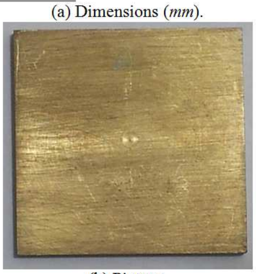
In electronic systems, a heat sink is a passive heat exchanger that cools a device by dissipating heat into the surrounding medium. In computers, heat sinks are used to cool central processing units or graphics processors. Heat sinks are used with high-power semiconductor devices such as power transistors and optoelectronics such as lasers and light emitting diodes (*LED*s), where the heat dissipation ability of the basic device is insufficient to moderate its temperature. A heat sink is designed to maximize its surface area in contact with the cooling medium surrounding it, such as the air. Air velocity, choice of material, protrusion design and surface treatment are factors that affect the performance of a heat sink [18].

The most common heat sink material is aluminum. Chemically pure aluminum is not used in the manufacture of heat sinks, but rather aluminum alloys. Aluminum alloy 1050A has one of the higher thermal conductivity values at 229 *W*/(*m K*). However, it is not recommended for machining, since it is a relatively soft material. Aluminum alloys 6061 and 6063 are the more commonly used aluminum alloys, with thermal conductivity values of 166 and 201 *W*/(*m K*), respectively. Copper is also used since it has around twice the conductivity of aluminum, but is three times as heavy as aluminum. Copper could be around four to six times more expensive than aluminum. Copper heat sinks are machined and skived. Another method of manufacture is to solder the fins into the heat sink base [19].

In the present work, a square piece of copper, Figure 7, was used as a heat sink. It is 45 *mm* × 45 *mm* with 4 *mm* thickness. Its surfaces were prepared by a grinding machine. This heat sink is directly attached to the lower surface of the Peltier thermo-electric module to increase the temperature difference between the module upper and lower surfaces; thus, increasing the output current.



(a) Dimensions (*mm*).



(b) Picture.

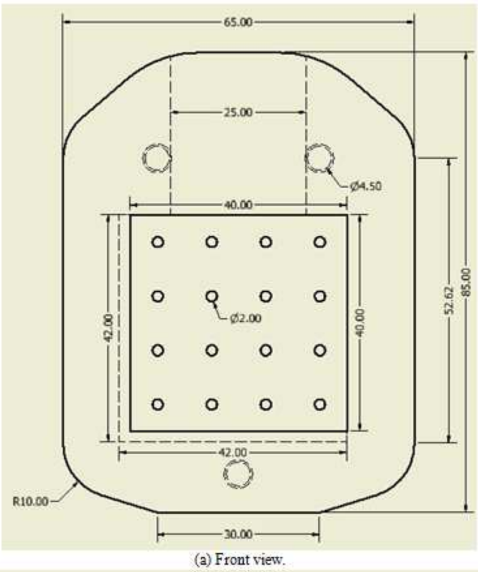
Figure 7. *Copper heat sink.*

2.2.2. Housing

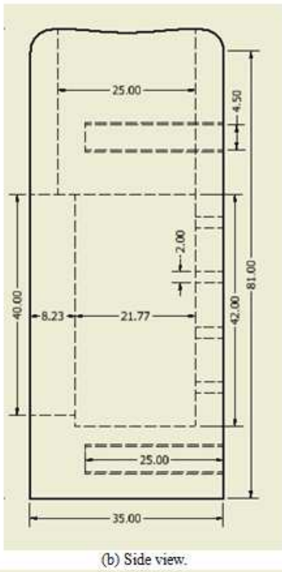
Teflon was chosen as the material of the housing of the present model of the hand lamb. Teflon is the brand name of a compound that was discovered by Roy J. Plunkett (1910-1994) of DuPont in 1938 and introduced as a commercial product in 1946. Teflon's chemical name is polytetrafluoroethylene, or *PTFE*, which is a polymer of fluoride and ethylene. *PTFE* has the lowest coefficient of friction of any solid. It is used as a non-stick coating for cookware. *PTFE* is very un-reactive, and so is frequently used in containers and pipe-work for reactive chemicals. Its melting point varies between 260 *°C* (*FEP*) and 327 *°C* (*PTFE*), depending on the specific Teflon polymer. Moreover, *PTFE* has excellent electrical properties especially at radio frequencies, making it highly suitable for use in insulation in cables and connector assemblies. Coupled with its high melting temperature, this makes it the material of choice as a substitute for the weaker polyethylene which is frequently used in low-cost applications [20].

Thus, Teflon is an appropriate material for housing because it has good thermal insulation and its light weight. Also, it is not expensive. The housing of the present model was designed to contain all the components of the hand lamp. These components include Peltier thermo-electric module, electronic chip, heat sink, wires, and a group of nine *LED*s.

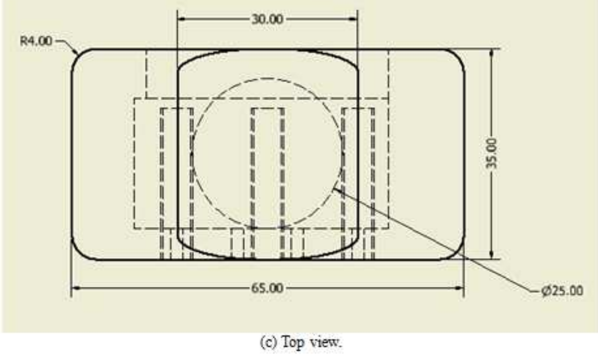
Figure 8 shows the detail drawings and dimensions of the assembled housing. The housing was manufactured by a group of operations including lathe, milling, drilling, and polishing machining. Figure 9 illustrates pictures of the housing after manufacturing. As can be seen in Figure 9, the housing was divided into two parts for ease of assembly. The size of the housing was chosen to make it easy to be hold by the hand of a grown-up person.



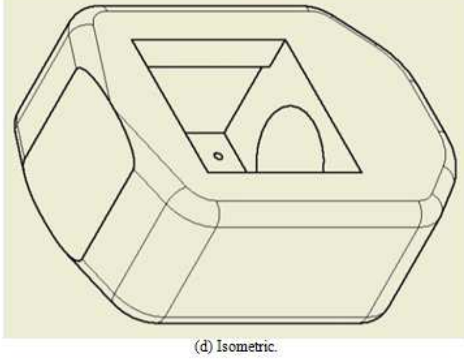
(a) Front view.



(b) Side view.

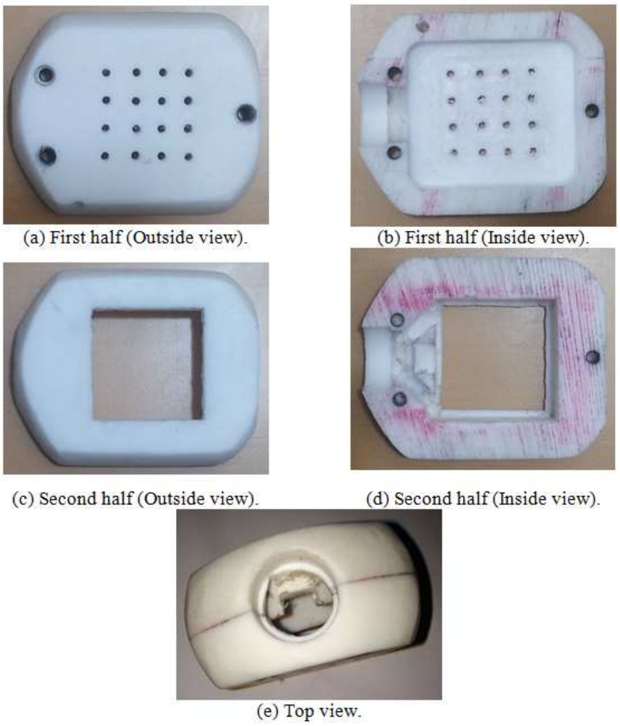


(c) Top view.



(d) Isometric.

Figure 8. *Details and dimensions of the model housing (mm).*



(a) First half (Outside view). (b) First half (Inside view). (c) Second half (Outside view). (d) Second half (Inside view). (e) Top view.

Figure 9. *Pictures of the manufactured housing.*

3. Assembly and Test of the Present Model

3.1. Assembly of the Present Model

After manufacturing the different parts of the model, assembly phase took place. The assembly process can be simply summarized in the following sequential steps, which are illustrated in Figure 10:

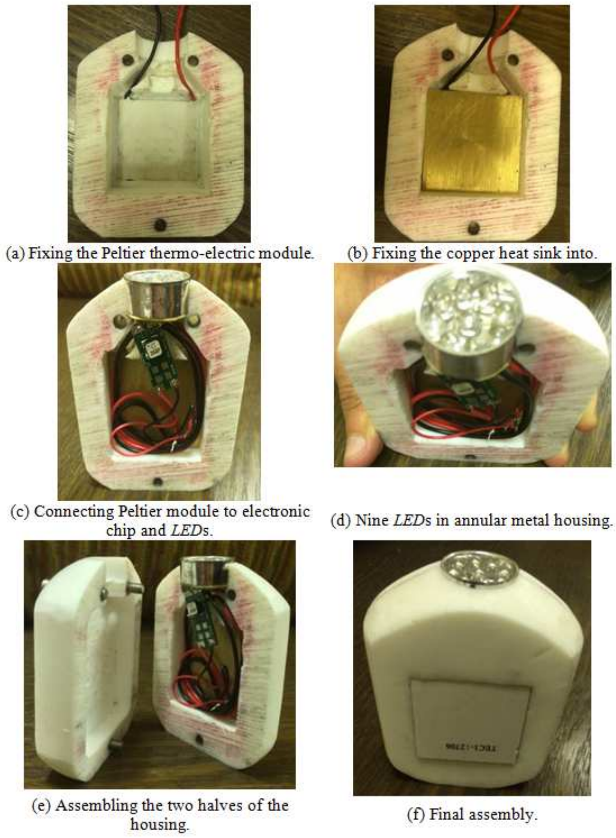
i. Fixing the Peltier thermo-electric module in its place in the second half of the housing, Figure 10a. The upper surface of the module will be in direct contact with the inside of the human hand. The lower surface of the module is in direct contact with the upper surface of the heat sink.

ii. Fixing the copper heat sink into place with direct contact to the lower surface of the Peltier thermo-electric module, Figure 10b.

iii. Connecting the two wires of the Peltier module to the electronic chip and the *LED*s, Figure 10c. A group of nine suitable *LED*s were enclosed in an annular metal housing, which was placed into place in the housing, Figure 10d.

iv. Assembling the two halves of the housing together by the three bolts, Figure 10e. The first half of the housing has an array of 16 vents (each of 2 *mm*-diameter) for cooling, Figure 9a.

v. Finally, the model is assembled and ready for use, Figure 10f.



(a) Fixing the Peltier thermo-electric module. (b) Fixing the copper heat sink into. (c) Connecting Peltier module to electronic chip and *LED*s. (d) Nine *LED*s in annular metal housing. (e) Assembling the two halves of the housing. (f) Final assembly.

Figure 10. *Pictures of the assembly steps.*

3.2. Test of the Present Model

After successfully assembling the present model, it was tested by holding in hand, Figure 11. As it appears from Figure 11, the model operates as it should be.

Figure 11. *Present model in hand.*

Figure 12 illustrates how the present model operates. When the hand is away from the upper surface of the Peltier module, *LED*s are off (no light), Figure 12a. As the hand touches the Peltier module, *LED*s start to operate because of the hand heat, Figure 12b. Then, shortly, *LED*s operate with full power (maximum light), Figure 12c. The light weakens as the hand gets out of the model, Figure 12d. Finally, *LED*s light vanishes, Figure 12e.

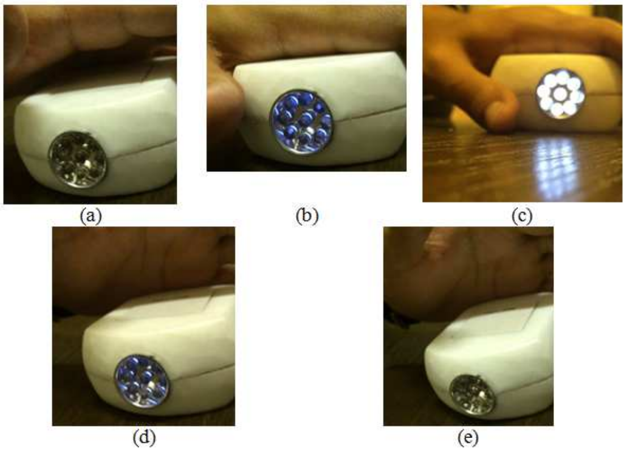


Figure 12. *Operation of the present model.*

The test revealed that the present model needs cold weather to increase the lighting strength. The lower the surrounding temperature, the better is the operation of the present hand lamp. This is attributed to the increase of the temperature difference of the upper and lower surfaces of the Peltier module. Also, the increase of the size of the heat sink and connecting it to the outer surface of the model housing may increase the efficiency of the hand lamp.

Although the weight of the present model is not big (about 0.4 *kg*), using another material for the housing may be a good idea. Other materials such as plastic, *PVC* or fiberglass may be suggested because of their lighter weight and cheaper price in comparison to Teflon.

4. Conclusions

After the test of the present model and based on the above illustrations and observations, the following points can be stated:

- i The present technique, of utilizing the human-emitted heat for providing the hand lamp with electricity, proved to be successful and totally applicable.
- ii The design of the present proposed model is simple and easy to manufacture and implement.
- iii The present hand lamp gives enough light for personal applications.
- iv The tests suggest the use of other materials for the lamp housing such as plastic, *PVC* or fiberglass because of their lighter weight and cheaper price in comparison to Teflon.
- v The real practice revealed that the present model needs cold weather to increase the lighting strength.
- vi The increase of the size of the heat sink and connecting it to the outer surface of the model housing may increase the efficiency of the hand lamp.

Ideas for Further Development

Considering the above discussions and concluding points, the following ideas can be listed:

- i Feasibility study is to be carried out for mass production and marketing of the present model.
- ii The lamp may be redesigned for the workers' helmet or their shoulder. In such a case, the worker hand is free for his practice and light is directed to the spot of the work.
- iii The same principle may be extended to use the human emitted-heat for charging small electronic devices such as cellular phones, ipads, *etc*.

Nomenclature

A, B	Materials of the junction of Peltier module.
AC	Alternating current
DC	Direct current.
FEP	Fluorinated ethylene propylene.
I	Peltier module current.
LED	Light-emitting diode.
PTFE	Polytetrafluoroethylene (polymer of fluoride and ethylene).
PVC	Polyvinyl chloride.
Q	Peltier heat absorbed by the lower junction per unit time.
Qc_{max}	Maximum cooling power of Peltier module.
T_1	Temperature of the lower junction of Peltier module.
T_2	Temperature of the upper junction of Peltier module.
T_{max}	Maximum temperature differential of Peltier module.
TEM	Thermoelectric module.
Π_A	Peltier coefficient of material A.
Π_B	Peltier coefficient of material B.
Π_{AB}	Peltier coefficient.

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