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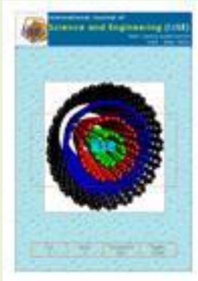

An Extensive Study of Thermo-electric Effect

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Abstract *- In well known thermo-electric effect (i.e. in thermo-couples generally used in college laboratories) the maximum temperature difference between the junctions approaches 100°C resulting in small magnitude of the current and potential difference produced. These are in the micro range. To have higher currents and potential differences a different type of experiment is to be performed. In this work an experiment has been proposed where thermo-electric effect is observed more prominently for different temperatures of a hotter conductor while keeping another conductor fixed at lower temperature (generally the room temperature) making the temperature difference too high resulting in the current and potential difference to increase. Experiment has also been performed to increase the thermo-electric power by joining a number of thermo-couples.*

Keywords—*Thermo-electric effect, Seebeck effect, thermo-panel*

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I. Introduction

Thermo-electric effect is nothing but the direct conversion of temperature difference to electric potential difference. This is a reversible effect. The first thermo-electric effect was discovered in 1821 by T.J.Seebeck (H.J.Goldsmid, 2016, Christophe Goupil, 2016). This is nothing but the production of potential difference by heating one of the two junctions formed by two dissimilar electrical conductors. In 1834 J. Peltier observed the second thermo-electric effect (Christophe Goupil, 2016). The next thermoelectric effect is Thomson effect (Christophe Goupil, 2016, Thomson, W. 1851) which is related to the e.m.f. that develops between two parts of the same conductor when they are at different temperatures. If two parts of the conductor are at small temperature difference dT, then the electric potential difference dV is proportional to dT or $dV=\sigma dT$ where σ is the constant of proportionality and is known as Thomson co-efficient. It is to be noted that Seebeck and Peltier effects occur only at the junctions of two dissimilar conductors which suggest that these effects are interfacial phenomena but depend on the bulk properties of the materials involved.

The underlying principle of the first experiment is that:- when a conductor is heated the conducting electrons become excited due to increase of their thermal energy (or thermal velocity). If this hot conductor comes in contact with another (may be a similar or dissimilar one) at lower temperature, the conducting electrons diffuse to the later. If a complete circuit is formed then this flow of electrons will generate a current which subsequently produce a potential difference between the two.

If the temperature difference between the two conductors coming in contact be large enough, then the potential difference produced may be in the mV order. Several workers have studied the effect with different conductors.

In this work an experimental arrangement related to Thomson effect is put forward by which we may get thermo-e.m.f.s in the range of milli-volt and then, an experimental arrangement connected to Seebeck effect has been done by which one may generate thermo e.m.f.s and electric current in the range of several volt and ampere.

II. Material and Method

A meter M (for measuring current or potential difference) is connected to two copper wires. A and B are the other ends of the wires. The terminal B may be plain as in figure 1(a) or it may be coiled (either a coil of several turns or co-axial coils) as in figure 1(b). This terminal may be heated to high temperature while A is kept at room temperature. If B is made to touch the cold end A suddenly, a continuous current starts to flow which attains its maximum very quickly.

The maximum current and potential difference are read. It is seen that the current and potential difference dies out instantaneously since the temperature difference between A and B does so. The dying out time may differ with the material of the wires, the area of contact of the wires (i.e. variation of contact resistance), presence of other materials close to the set up which may affect the thermal radiation mainly from B.

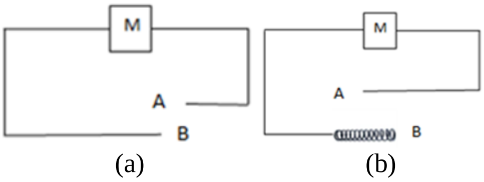

Figure 1. Circuit connections used

In this experiment the heat of the flame of a candle (www.kristallikov.net/page52e.html) at different colored regions (Wikipedia.org/wiki/ color temperature) are used as source of heating the terminal B. The temperature of the regions having different colors of the flame of a candle are shown in figure 2.

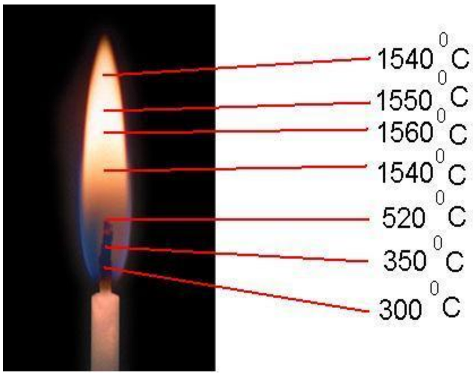

Figure 2. Temperature of different regions of a candle flame having different colors; Source: www.kristallikov.net/page52e.html

It is to be noted that when the heated end B is taken out of the flame its temperature decreases rapidly due to radiation. This radiation loss could, to some extent, be reduced by making the end B coiled as shown in figure 1(b).

Readings of maximum voltage and current are taken when B, at different high temperatures suddenly touches A. The readings are shown in table-1 and graphically in figure 3. The experiment implies that flow of thermal energy through a junction or any section of a conductor produces electric current.

Table-1. Variation of voltage and current with temperature difference

No.of observations.	Temperature of B (T_1) in °C	Temperature of A (T_2) in °C	Temperature difference (T_1- T_2) in °C	Meter reading in milli- volt	Meter reading in micro-ampere
1	30	30	0	0	0
2	350	30	320	35	21
3	520	30	490	55	32.5
4	800	30	770	95	56
5	1540	30	1510	210	125
6	1560	30	1530	215	127

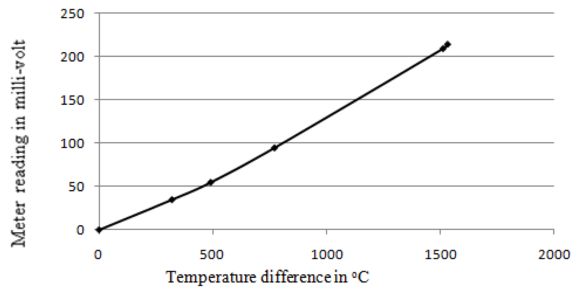

Figure 3. Variation of voltage with temperature difference

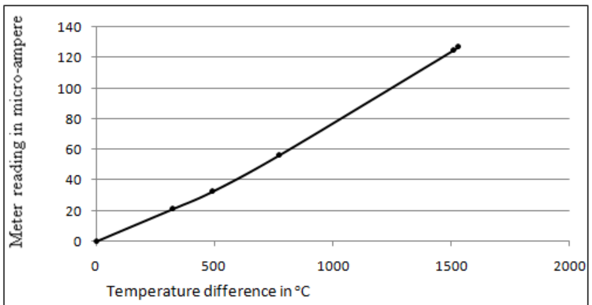

Figure 4. Variation of current with temperature difference

Use of Thermo-couple as an Electric Power Generator

One can connect a number of thermo-couples with series combination as shown in figure 5. Here, A is the region of junctions which are at low temperature (room temperature) and B is the region of junctions which is heated.

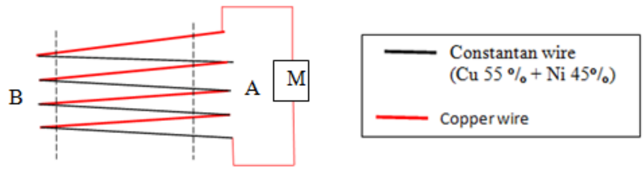

Figure. 5. Series connection of thermo-couples

The readings of voltage and current for different number of junctions connected in series combination are given in table-2. Here, the junctions of region B is heated with kerosene flame (990ºC) (wikipedia.org/wiki/Flame). In our experiment every junction is made by copper and constantan (Cu 55 o/o + Ni 45o/o) wire. Constantan is collected from the coil of rheostat and its composition is written from (www.electrical4u.com/materials-used-for-rheostats).

Table- 2. Change of voltage and current with number of junctions connected in series

No. of observations	Length of the wire in cm	Number of junctions	Meter reading in milli- volt	Meter reading in milli-ampere
1	25	1	20	25
2	25	2	41	28
3	25	3	60	34
4	25	4	80	31
5	25	5	100	28
6	25	6	120	26

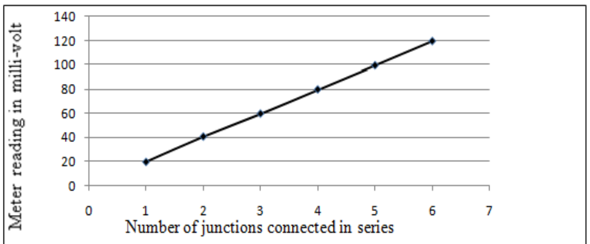

Figure 6. Change of voltage with number of junctions connected in series

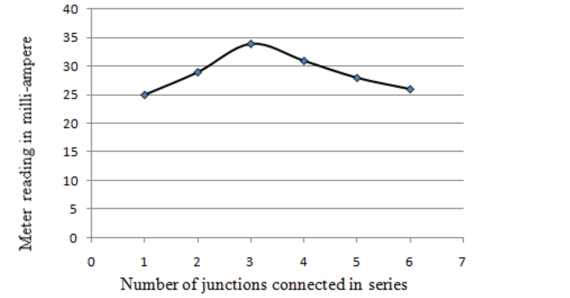

Figure 7. Change of current with number of junctions connected in series

The result of the experiment show that voltage increases with increase of number of junctions connected in series but current increases with small increase of the number of junctions and then decreases rapidly.

One can connect a number of thermo-couples with parallel combination as shown in figure 8(a). Here, A is the region of junctions at low temperature (room temperature) and B is the hot one.

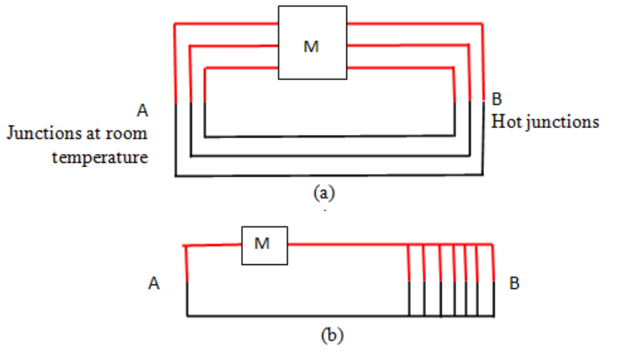

Figure 8. Parallel connection of thermo- couples

Now, length between A and B is comparatively small and one can use the circuit as shown in figure 8(b) for parallel combination instead of figure 8(a). Here, in figure 8(b), a number of parallel junctions connected in region B and A constitute a single junction. Now, connecting the wires using figure 8(b) we obtain the results given in table-3 and figure 9.

Table -3. Change of voltage and current with number of junctions connected in parallel

No.of obser-vations	Length of the wire in cm	Number of junctions in parallel combination	Meter reading in milli- volt	Meter reading in milli- ampere
1	6	1	40	70
2	6	2	40	100
3	6	3	40	160
4	6	4	40	200
5	6	5	40	240
6	6	6	40	280
7	6	7	40	310
8	6	8	40	370

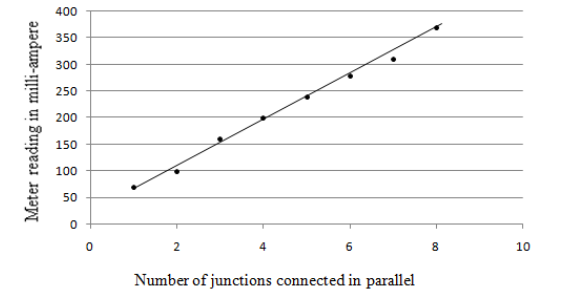

Figure 9. Change of current with number of junctions connected in parallel

It is also pointed out that voltage is unchanged with change of the number of junctions at a fixed temperature difference and length of wires connected in parallel combination. But, electric current is increased with increase of number of said junctions. The result of the experiment show that voltage increases with increase of number of junctions connected in series but current decreases rapidly. It is pointed out that when number of junctions is increased then, length of the total wire would be increased and resistance increases. Therefore, current decreases with increase of number of junctions. It is already seen that voltage increases with increase of number of junctions connected in series but current increases with small increase of the number of junctions and then decreases rapidly due to increase of length of the wire as well as resistance of it. Now, Table- 4, figure 10 and figure 11 show respectively the change of voltage and current with length of the wire between two junctions hot and cold.

Table 4. Change of voltage and current with length of the wire between junctions.

No. of observations	Length of the wire in cm	Meter reading in milli- volt	Meter reading in milli- ampere
1	6	40	90
2	10	36	62
3	20	31	30
4	30	28	16
5	40	26	09
6	50	25	05

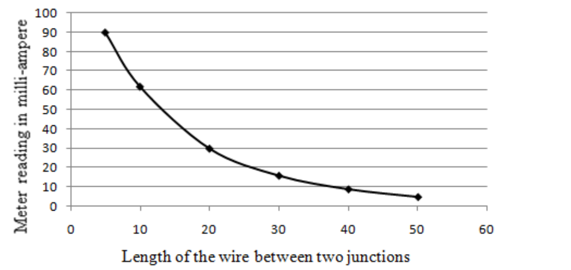

Figure 10. Change of current with length of the wire between two junctions

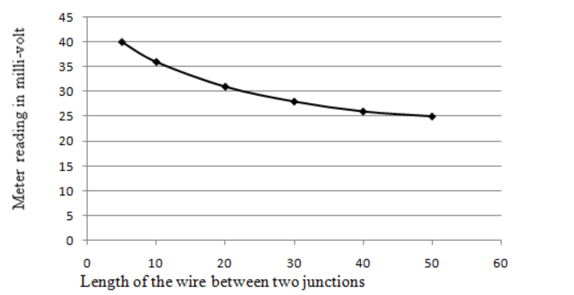

Figure 11. Change of voltage with length of the wire between two junctions

III. RESULT AND DISCUSSION

The results obtained show the following characteristics :

1. If length of the wire between two junctions, hot and cold, be comparatively small keeping sufficient temperature difference between them then, meter readings would go up.
2. If the junctions are connected in series combination satisfying condition 1 then voltage increases but current decreases.
3. If the junctions are connected in parallel satisfying the first condition then current increases keeping voltage approximately steady.

Now, following the above criterion of the results one can connect a large number of thermo-couples in parallel combination which may be called a module and then connect a number of such modules in series as shown in figure 12.

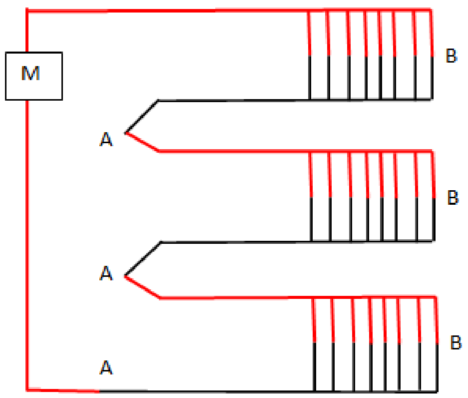

Figure 12. Connection of three modules in series

Table 5. Voltage and Current for 5 junctions in a module

Number of parallel junctions connected in a module	5
Number of modules connected in series	5
Length of wire between two terminals	5 cm
Temperature of hot junctions (B)	990^{O}C, Temperature of kerosene flame
Temperature of cold junctions (A)	30^{O}C, Room temperature
Meter reading in volt	0.15 Volt
Meter reading in ampere	0.11 Amp

It is pointed out that temperature of each parallel junction in the region B of each module in figure 8(b) should be same. Otherwise, two adjacent parallel junctions form a thermocouple locally and meter reading decreases.

However, choosing the suitable combinations and a number of junctions in a small region following figure 12 one may get meter reading in volt and ampere. Now, the result in the table given below is for a trial which is easily done in our laboratory using the set up of figure. 12.

It is also pointed out that meter readings for one thermo-couple are 30 milli-volt and 100 milli- ampere keeping temperature difference and length between two junctions the same as shown in the above table.

IV. CONLUSIONS

In first experiment it is seen that when hot end of a wire be touched to the cold end of another a large temperature difference exists between two sides of the junctions which is the cause of electric current through the circuit. This phenomenon implies that flow of thermal energy through a conductor creates electric current.

We know that connecting a number of photo-diodes a solar panel is made. Similarly connecting a number of thermo-couples as shown in figure 12 one can make thermo-panel from which we may get usable electrical energy.

Solar panel can work at normal temperature but thermo-panel is effective at high temperature. So, more study is necessary due to the fact that we have to find out such materials that will show better result of Seebeck effect at a temperature not more than boiling point of water. Then we can use this as an electric power generator in large scale.

For first set up we may say that although the method cited here is a crude one yet, in spite of all its drawbacks, it may be used for approximate measurement of temperature of a hot body by knowing the thermo-e.m.f. produced after it comes in contact with another one at lower temperature.

This is a method where no junction of two dissimilar metals is required. Similar or dissimilar metals with open ends may serve the purpose of temperature measurement.

Again, the studies in this work with the second set up reveals that large number of thermo-couples, used in series and or parallel could be used as thermo-electric generators.

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