Thermoelectric Power

By

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1. Introduction

- The pioneer of thermoelectric was a German scientist **Thomas Johann Seebeck** (1770-1831)

- **Thermoelectricity** refers to the phenomena in which a temperature difference creates an electric potential or an electric potential creates a temperature difference.

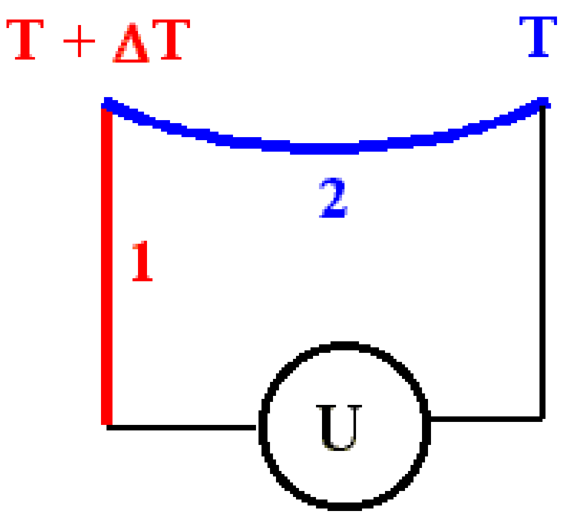
- ***Thermoelectric power generator*** is a device that converts the heat energy into electrical energy based on the principles of Seebeck effect.

- Later, In 1834, French scientist, **Peltier** and in 1851**, Thomson** described the thermal effects on conductors

2. Seebeck, Peltier and Thomson effect

Seebeck effect

When the junctions of two different metals are maintained at different temperature, the emf is produced in the circuit. This is known as Seebeck effect.



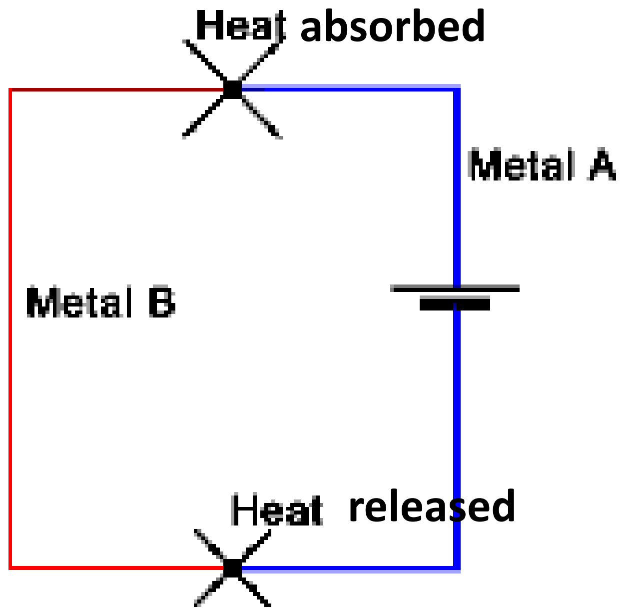
The conductor 1 is maintained at T+Δ***T*** temperature

The conductor 2 is maintained at temperature 'T'.

Since the junctions are maintained at different temperature, the emf 'U' flows across the circuit.

Peltier effect

Whenever current passes through the circuit of two dissimilar conductors, depending on the current direction, either heat is absorbed or released at the junction of the two conductors. This is known as Peltier effect.



Thomson effect

Heat is absorbed or produced when current flows in material with a certain temperature gradient. The heat is proportional to both the electric current and the temperature gradient. This is known as Thomson effect.

3. Thermoelectric effect

The thermoelectric effect, is the direct conversion of heat differentials to electric voltage and vice versa..

4. Thermoelectric materials

- The good thermoelectric materials should possess

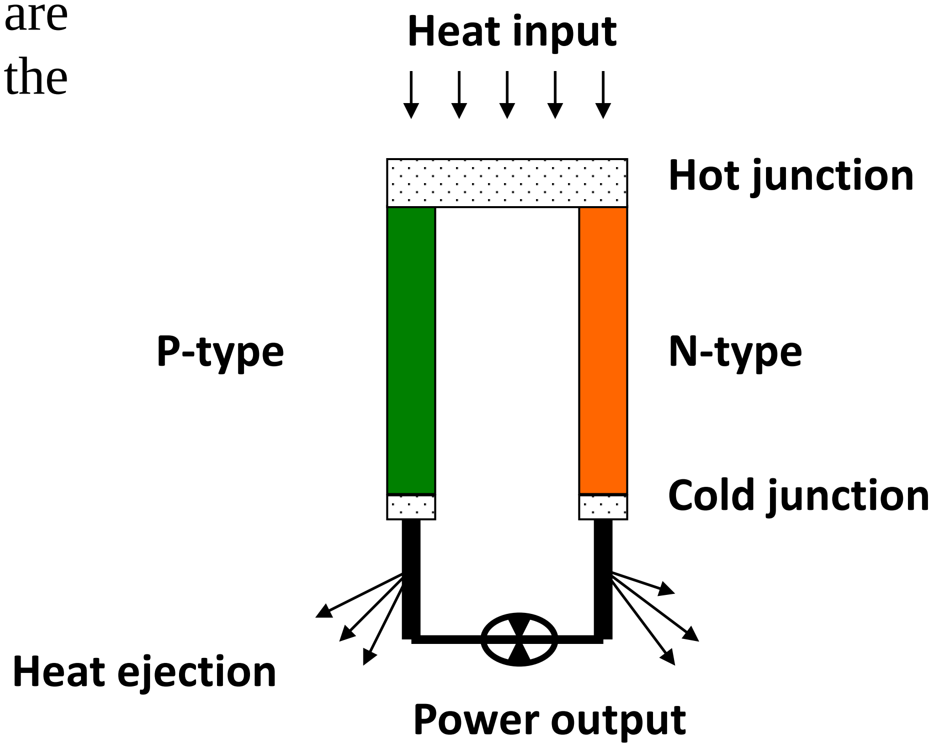
  1. Large Seebeck coefficients
  2. High electrical conductivity
  3. Low thermal conductivity

- The example for thermoelectric materials

  - BismuthTelluride (Bi_2Te_3),
  - Lead Telluride (PbTe),
  - SiliconGermanium (SiGe),
  - Bismuth-Antimony (Bi-Sb)

6. Principle, construction and working of Thermoelectric power generator

Thermoelectric power generator based on the principle of **Seebeck effect** that when the junctions of two different metals are maintained at different temperature, the emf is produced in the circuit



- In a thermoelectric material there are free carriers which carry both charge and heat.

- Perhaps the simplest example is a gas of charged particles.

- If a gas is placed in a box within a temperature gradient, where one side is cold and the other is hot, the gas molecules at the hot end will move faster than those at the cold end.

- The faster hot molecules will diffuse further than the cold molecules and so there will be a net build up of molecules (higher density) at the cold end.
- The density gradient will cause the molecules to diffuse back to the hot end.
- In the steady state, the effect of the density gradient will exactly counteract the effect of the temperature gradient so there is no net flow of molecules.
- If the molecules are charged, the buildup of charge at the cold end will also produce electric potential.

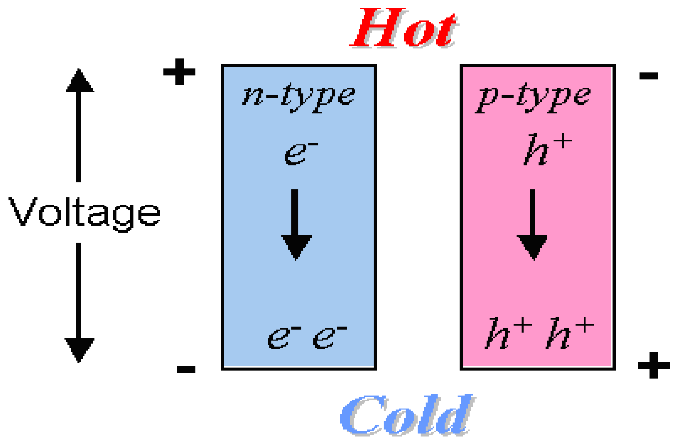


Diagram shows

The charge buildup at cold side

- The electric potential produced by a temperature difference is known as the Seebeck effect and the proportionality constant is called the Seebeck coefficient.
- Potential difference developed per unit temperature difference is called Seebeck coefficient and is given by ,

$$S=dV/dT$$

- If the free charges are positive (the material is p-type), positive charge will build up on the cold which will have a positive potential.
- Similarly, negative free charges (n-type material) will produce a negative potential at the cold end.

Sign of Seebeck coefficient:

HOT		COLD	S
⊕	*When e^- flows* → *from hot to cold end*	e^-	**Negative** (n-type semiconductor)
e^-	*When holes diffuse* → *from hot to cold end*	⊕	**Positive** (p-type semiconductor)

Types of thermocouple:

Thermocouple	Name	Sensitivity	Temp. measurement range
K-type	Chromel-Alumel	41mv/ ^{o}c	-200^{o}c → +1350^{o}c
E-type	Chromel- constantan	68mv/ ^{o}c	Low temp.
J-type		55 mv/ ^{o}c	-45^{o}c → +750^{o}c
N-type	Nicrosil- nickel	39mv/ ^{o}c	-80^{o}c → 1200^{o}c
S-type	Platinum-10% rhodium	35mv/ ^{o}c	-40^{o}c → +1600^{o}c
T-type	Copper- constantan	43mv/ ^{o}c	-200^{o}c → +350^{o}c
R-type	Platinum- 7% rhodium	41mv/ ^{o}c	-200^{o}c → +750^{o}c
C-type	Tungsten 5%- rhenium- tugston26%- rhenium		0^{o}c → +2320^{o}c
M-type	Nickel alloy		1400^{o}c
B-type	Platinum- rhodium		1800^{o}c

Applications:

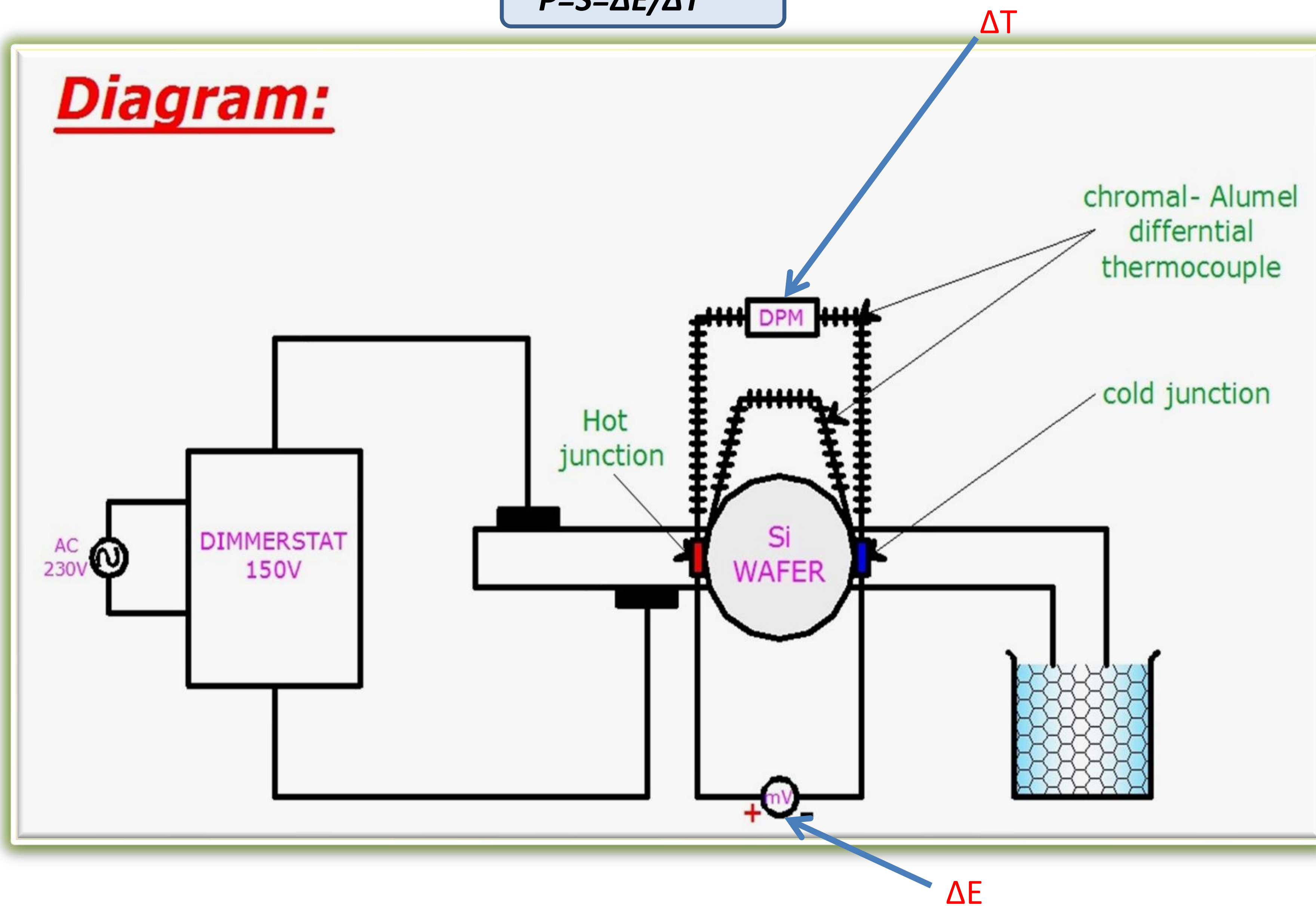
1. In power production.
2. In industries for temperature measurement for kilns, gas,turbines,exhaust diesel engines.
3. In steel industries to monitor the temperature.
4. **Thermopiles-**It is an device that converts thermal energy into electrical energy by connecting several thermocouples in series or parallel.
5. **Thermoelectric generators:** (S.B.) coverts heat directly into electrical energy.
6. **Automotive generator: W**aste heat in industries in internal combustion machine.
7. Radio isotope TE generator.
8. For heating purpose-oven, water heater etc.

Thermoelectric Effect

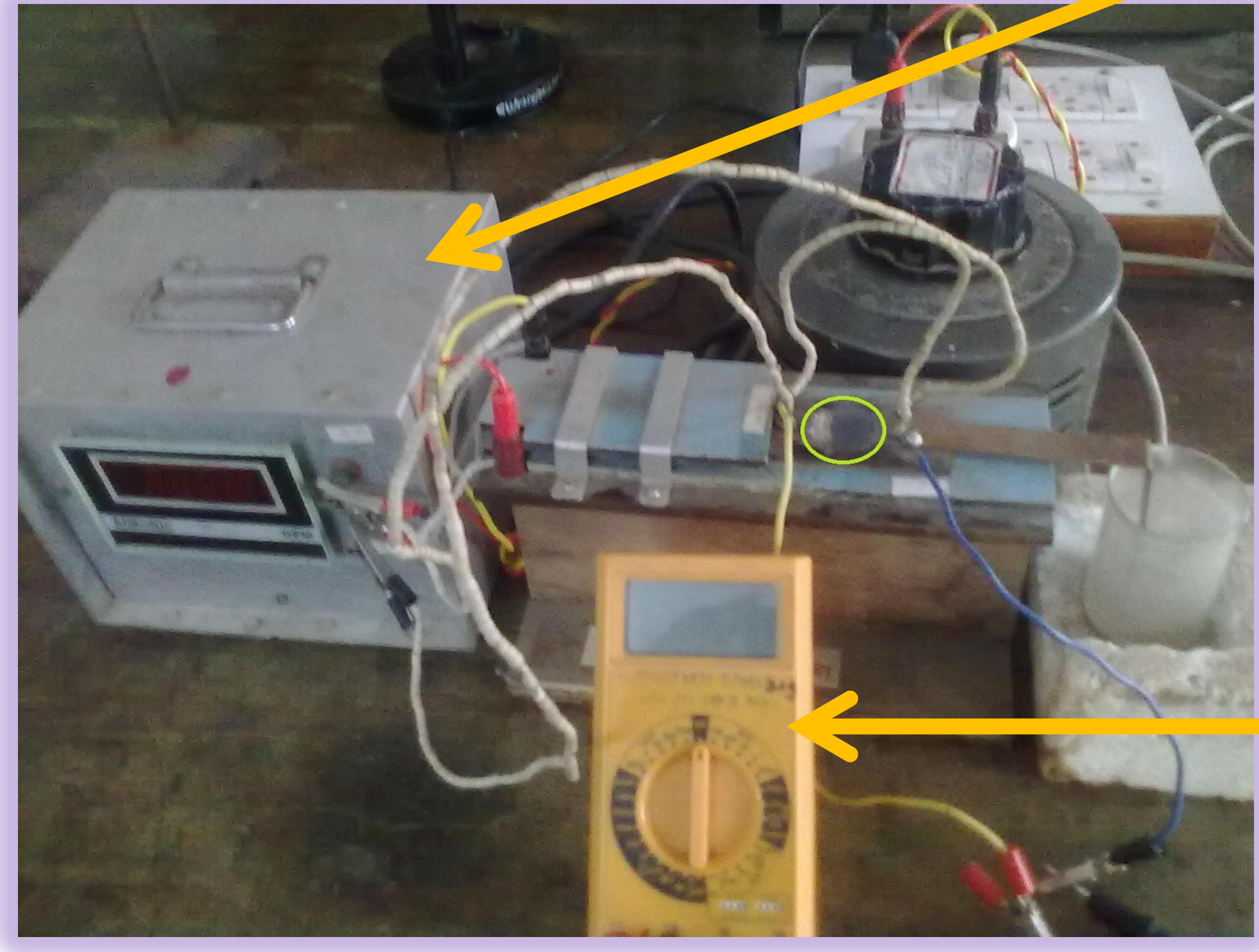
Aim: To determine the thermoelectric power of a given n-type semiconductor.

Apparatus: AC supply (230v), dimmer stat, digital panel meter(DPM), Si- wafer, thermocouple etc.

$$P=S=\Delta E/\Delta T$$



Actual setup of experiment:



(thermo Couple voltage)

(emf)

Observation Table:

Obs.No.	Thermocouple voltage(mv)	Temperature Difference ΔT(^{o}C)	Thermo-emf ΔE(mv)
1.	5.1	127.5	2.6
.	.	.	.
.	.	.	.
.	.	.	.
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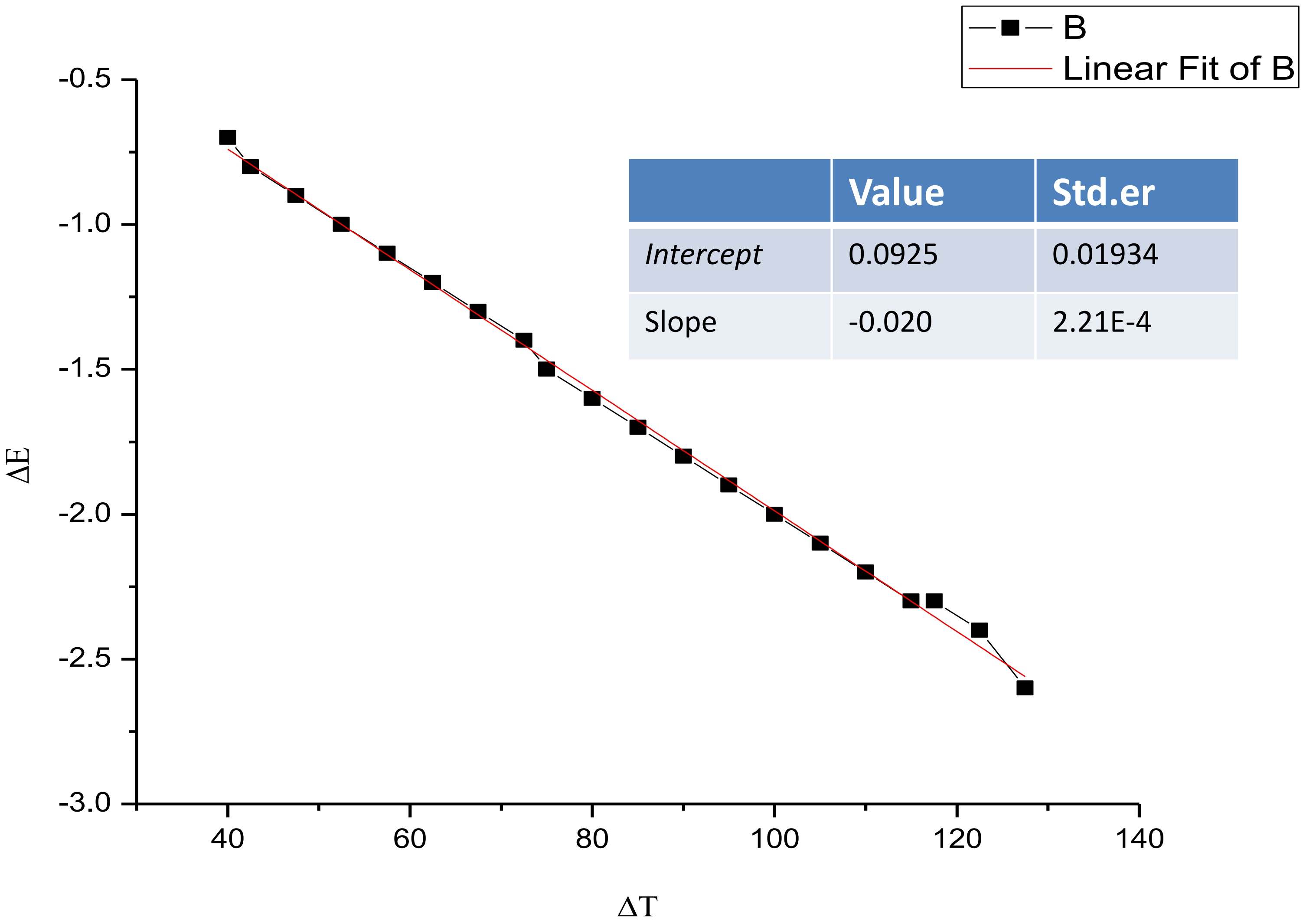

	Value	Std.er
Intercept	0.0925	0.01934
Slope	-0.020	2.21E-4

Formula:

Thermoelectric Power=$P=\Delta E/ \Delta T$

Where,

ΔE =change in emf developed across semiconductor due to temperature ΔT.

Convertion Factor:

1 mV=25^{0}c …………..{for chromel-alumel}

Result:

Thermoelectric power of a given n- type semiconductor is = ...mv/^{o}c.