Chapter 3: Thermoelectric Effect

Short Answer Questions

1. 2076 Set B Q.No. 1b 2059 Q.No. 10 a **What is thermoelectric effect?** [2]

If two different metal wires are joined to form a closed circuit and two junctions are kept at different temperatures, a small emf is set up in the circuit and small current flows in the circuit in a definite direction. This effect is called thermoelectric effect or Seebeck effect which is discovered by a German physicist Thomas J Seebeck. This thermoelectric effect is defined as the phenomenon of conversion of heat energy into electrical energy when the junction of two dissimilar certain metals (thermocouple) are kept at different temperatures. The emf developed in the circuit is called thermo emf and the current is called thermoelectric current. Thus the electromotive force developed in the thermoelectric effect is called thermoelectric emf or thermo emf or Seebeck emf. The value of thermo emf depends on:

(a) the temperature of hot junction of thermocouple and

(b) the nature of material chosen from the thermoelectric series.

2. 2076 Set C Q.No. 1b **If the temperature of cold junction of a thermocouple is lowered, what will be the effect on neutral temperature and the temperature of inversion?** [2]

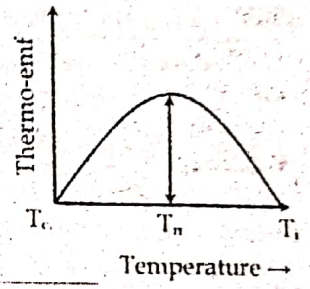
When the temperature of hot junction increases, the thermo-emf increases at first, reaches to a maximum value called neutral temperature and then reduces to zero called temperature of inversion. The temperature of the hot junction at which thermo-emf is reduced to zero and changes its polarity is called temperature of inversion. The temperature of inversion is shown in the given graph. The temperature of inversion depends upon the temperature of cold junction and the nature of metals used in the thermocouple.

The temperature of cold junction, temperature of inversion and neutral temperature are related as

$$T_n = \frac{T_c + T_i}{2}$$

or, $T_i = 2T_n - T_c$.

If temperature of cold junction decreases, then temperature of inversion increases and neutral temperature decreases.



3. 2075 Set A Q.No. 1c 2073 Supp Q.No. 1b 2070 Sup (Set A) Q.No. 1 f 2068 Q.No. 1 b **Does the thermoelectric effect obey the law of conservation of energy? Justify?** [2]

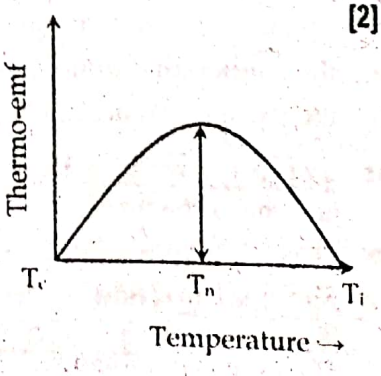
Yes, the thermoelectric effect obeys the law of conservation of energy. The thermoelectric effect is defined as the process of production of small emf in the circuit when the two dissimilar metals are joined end to end and two ends are kept at different temperature. Here, the heat energy is converted to electrical energy and hence obey the law of conservation of energy.

4. 2075 Set B Q.No. 1b **Why is Lead (Pb) used as a standard reference metal in thermo-electricity?** [2]

From experimental investigation, Seeback became able to arrange a number of metals in a series in thermoelectricity called thermoelectric series. The series is given as Ag, Au, Cr, Sn, Pb, Cu, Co, Ni, Bi. The series was made in such a way that if any two of them form a thermo-couple, the current will flow from the metal which is earlier in the series to the metal which is later in the series through out the cold junction. The lead (Pb) lies in middle and taken as standard references metal in thermo-electricity as the thermo emf of lead is almost zero.

5. 2074 Supp Q.No. 1c 2069 (Set A) Q.No. 1c 2068 Can. Q.No. 1c **What is temperature of inversion? On what factors does it depend?** [2]

When the temperature of hot junction increases, the thermo-emf increases at first, reaches to a maximum value called neutral temperature and then reduces to zero called temperature of inversion. The temperature of the hot junction at which thermo-emf is reduced to zero and changes its polarity is called temperature of inversion. The temperature of inversion is shown in the given graph. The temperature of inversion depends upon the temperature of cold junction and the nature of metals used in the thermocouple.



6. 2074 Set B Q.No. 1c **What is temperature of inversion? How does it change, if temperature of cold junction decreases?** [2]

Please refer to 2074 Supp Q.No. 1c

7. 2073 Set C Q.No. 1d **Point out the difference between Peltier and Seebeck effect in brief.** [2]

Seebeck's Effect: When two different metals are joined end to end to form a closed circuit such that two ends are kept at different temperatures, a small emf is developed in the circuit and small current flows in the circuit. This effect is called Seebeck effect. The amount of emf (current) depends up on the nature of two metals and temperature of hot junction. Heat energy is converted into electrical energy.

Peltier Effect: When a current is passed through a thermocouple whose junctions are at same temperature, heat is evolved at one junction and heat is absorbed at other junction and cooled. This effect is known as Peltier effect. The temperature difference of two junctions depends upon the amount of current flowing through the circuit. In Peltier effect, electrical energy is converted into heat energy. So, Peltier effect is inverse of Seebeck effect.

8. 2073 Set D Q.No. 1f **What is Seebeck effect? How is this effect different from Peltier effect? Explain.** [2]

Please refer 2073 Set C Q.No. 1d

9. 2072 Supp Q.No. 1e **On what factors does the temperature of inversion depend?** [2]

Please refer to 2074 Supp Q.No. 1c

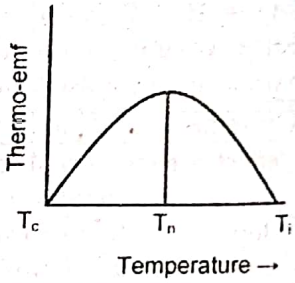
10. 2072 Set E Q.No. 1d **Is Seebeck effect reversible effect? Explain.** [2]

Yes, Seebeck effect is reversible effect. This is because on changing the hot and cold junction, the direction of thermo-current reverses its direction in Seebeck experiment.

11. 2071 Set D Q.No. 1 c **What is neutral temperature? On what factors does it depend?** [2]

When the temperature of hot junction increases in the thermocouple, the thermo-emf increases at first, reaches to maximum value called neutral temperature and then reduces to zero called temperature of inversion. Neutral temperature depends on the temperature of cold junction and nature of material of thermocouple. The relation between temperature of cold junction, neutral temperature and temperature inversion is given as

$$T_n = \frac{T_c + T_i}{2}$$



12. 2070 Set C Q.No. 1 c **Define temperature of inversion. If the temperature of cold junction of a thermocouple is lowered, what will be the effect on it?** [2]

Please refer to 2076 Set C Q.No. 1b

13. 2069 Supp Set B Q.No. 1 f 2069 (Set B) Q.No. 1c **Peltier effect is the converse of Seebeck effect. Explain** [2]

Please refer 2073 Set C Q.No. 1d

14. 2067 Q.No. 1b **What are the factors on which thermo-emf depends?** [2]

If we keep the junctions of two dissimilar metals making a loop at different temperatures, a current flows through it. An emf appears across the junction and is responsible for this current. This emf is called thermoelectric emf or thermo emf. The value of thermo emf depends on:

a. the temperature of hot junction of thermocouple and
b. the nature of material chosen from the thermoelectric series.

15. 2066 Old Q.No. 10 c **How does thermo emf change in a thermocouple when the temperature of the hot junction is changed?** [2]

Please refer to 2071 Set D Q.No. 1 c

16. 2062 Q.No. 10 b **How is Seebeck effect different from Peltier effect? Explain.** [2]

Please refer to 2073 Set C Q.No. 1d

17. 2061 Q.No. 10 a **What are the factors on which the thermo emf produced in a thermocouple depends?** [2]

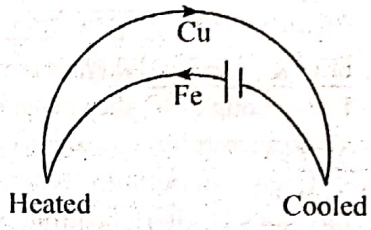
Please refer to 2067 Q.No. 1b

18. 2060 Q.No. 10 c **Why is Sb-Bi thermocouple preferred to Fe-Cu thermocouple?** [2]

The device, which is made by two different metal wires with their junction at different temperature is known as thermocouple. The value of thermo emf produced between two junctions of thermocouple depends on the position of metal in the thermoelectric series. The more distant the two elements in the thermoelectric series, the larger is the thermoelectric emf (or current) for a given differences of temperatures between the junctions of the couple. In the thermoelectric series, the position of Fe and Cu is at middle which have some common electrical properties but the position of Sb and Bi is at end. As a result, large amount of thermo electric current is produced by Sb-Bi thermocouple than that by Fe-Cu thermocouple. That's why Sb-Bi thermocouple is preferred to Fe-Cu thermocouple.

19. 2058 Q.No. 10 b **What do you mean by Peltier's effect?** [2]

When a current is passed through a thermocouple whose junctions are at the same temperature, heat is evolved at one junction and gets thus heated and heat is absorbed at the other junction and thus gets cooled. This effect is known as Peltier's effect. Thus Peltier's effect is defined as the phenomenon of generation or absorption of heat at the two junctions of thermocouple due to passing the current through it. This is the inverse of Seebeck effect. If the direction of the current is reversed, the previous cold junction becomes hot and vice versa.



Long Answer Questions

20. 2075 GIE Q.No. 5b **What is Seebeck effect? How does the thermo emf vary with the increase in temperature of hot junction, keeping cold junction at 0°c? Explain.** [4]

Seebeck Effect: If two dissimilar metals are joined at their ends so as to form a closed conducting circuit and if a difference of temperature is maintained at the two junctions, a small emf is produced, this effect in which heat can be converted into electricity is called seeback effect.

The thermocouple can be formed by using the metals such as Antimony, Iron, Zinc, Lead copper, Platinum, Bismuth, etc.

Variation of thermo-emf with temperature: Let us consider a Cu-Fe junction. Galvanometer is connected in the copper wire. Junction A is placed in hot water and B is placed in ice cold water as shown in figure. Keeping the junction B at 0°C and temperature of junction A is heated, the deflection in galvanometer is noted. For different temperature of hot junction, the variation of emf with temperature is shown in figure (i).

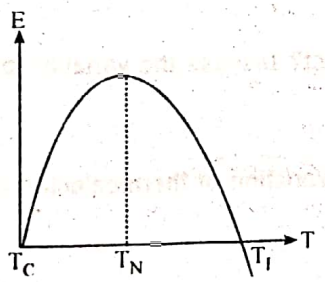


Figure (i)

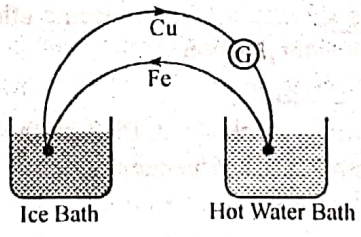


Figure (ii)

As the temperature of hot junction increases keeping cold junction at constant temperature(T_C), the thermo emf increases with the increase in temperature and has maximum at particular temperature called neutral temperature (T_N). If the temperature of hot junction is further increased beyond T_N, thermo emf decreases and becomes zero at particular temperature called temperature of inversion (T_I).

The temperature of inversion and neutral temperature are constant for a given thermocouple and neutral temperature independent of temperature of cold junction but inversion temperature depends

upon cold junction. It is found that neutral temperature is equal to arithmetic mean of inversion temperature and the temperature of cold junction.

i.e., $T_N = \frac{T_i + T_c}{2}$

If E is the thermo emf and T be the temperature of hot junction, then E and T are related as $E = aT + bT^2$ where a and b are constants.

21. 2074 Set A Q.No. 5b What is Seebeck effect? Explain the variation of thermo emf with gradual increase in the temperature of hot junction, keeping the cold junction at 0°c. [4]

Please refer to 2075 GIE Q.No. 5b

22. 2072 Set D Q.No. 5a What is thermoelectric effect? How does the thermo emf of a thermocouple vary with increase in temperature of hot junction, keeping cold junction at 0°C? Explain. [4]

Please refer to 2075 GIE Q.No. 5b

23. 2071 Supp Q.No. 5b What is seebeck effect? How does the emf of thermocouple vary with temperature of the hot junction? [4]

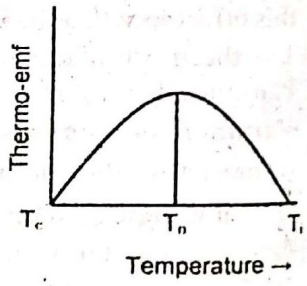
Please refer to 2075 GIE Q.No. 5b

24. 2071 Set C Q.No. 5 b What is a thermocouple? Define neutral temperature and temperature of inversion of a thermocouple. Are they constant for a given thermocouple? [4]

Thermocouple: The device, which is made by two different metal wires with their junction at different temperature is known as thermocouple. The value of thermo emf produced between two junctions of thermocouple depends on the position of metal in the thermoelectric series. The more distant the two elements in the thermoelectric series, the larger is the thermoelectric emf (or current) for a given differences of temperatures between the junctions of the couple. In the thermoelectric series, the position of Fe and Cu is at middle which have some common electrical properties but the position of Sb and Bi is at end. As a result, large amount of thermo electric current is produced by Sb-Bi thermocouple than that by Fe-Cu thermocouple. That's why Sb-Bi thermocouple is preferred to Fe-Cu thermocouple.

When the temperature of hot junction increases in the thermocouple, the thermo-emf increases at first, reaches to maximum value called neutral temperature and then reduces to zero called temperature of inversion. Neutral temperature depends on the temperature of cold junction and nature of material of thermocouple. The relation between temperature of cold junction, neutral temperature and temperature inversion is given as

$T_n = \frac{T_c + T_i}{2}$



They are not constant for a thermocouple because they depends upon the temperature of cold junction.

25. 2070 Supp. (Set B) Q.No. 5 a What is thermo electric effect? Discuss the variation of thermo emf with the change in temperature of the hot junction. [4]

Please refer to 2075 GIE Q.No. 5b

26. 2070 Set D Q.No. 5 b Define Seebeck effect. Discuss the variation of thermoelectric emf in a thermocouple with the increase of temperature of hot junction. [4]

Please refer to 2075 GIE Q.No. 5b

27. 2067 Sup Q.No. 5a What is thermoelectric effect? Discuss the variation of thermo-emf with the change in temperature of the hot junction. [1+3]

Please refer to 2075 GIE Q.No. 5b

28. 2063 Q.No. 11 a OR What is Seebeck effect? How does the thermo emf of a thermocouple vary with temperature of the hot junction?

Please refer to 2075 GIE Q.No. 5b

29. 2057 Q.No. 11 a What is Seebeck effect? How does the emf of a thermocouple vary with the temperature of the hot junction? [2+3]

Please refer to 2075 GIE Q.No. 5b

30. 2056 Q.No. 11 a OR Explain what do you mean by Seebeck Effect? How thermoelectric e.m.f. does vary with the temperature? [1+3]

Please refer to 2075 GIE Q.No. 5b

Numerical Problems

31. 2073 Set D Q.No. 9c The thermo-emf E and the temperature of hot junction θ satisfy a relation $E = a\theta + b\theta^2$, where $a = 4.1 \times 10^{-5}$ V $(°C)^{-1}$ and $b = -4.1 \times 10^{-8}$ V$(°C)^{-2}$. If the cold junction temperature is 0°C find the neutral temperature. [4]

Solution

The given equation is

$E = a\theta + b\theta^2$ .....(i)

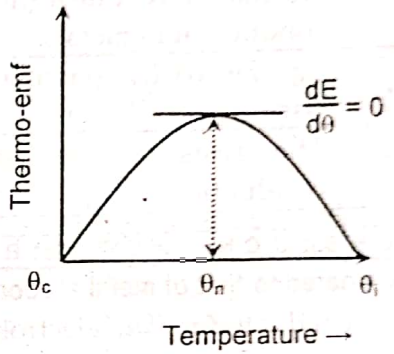
where, a & b are constant , θ = temperature of hot junction.

$a = 4.1 \times 10^{-5}$ V $(°C)^{-1}$, $b = -4.1 \times 10^{-8}$ V$(°C)^{-2}$

and temperature of cold junction is 0°C.

Now,

$$\frac{dE}{d\theta} = a + 2b\theta.$$



The neutral temperature is temperature of hot junction at which, thermo-emf is maximum i.e.

$$\frac{dE}{d\theta} = 0 \text{ or } a + 2b\theta_n = 0$$

or, $a = -2b\theta_n$

or, $\theta_n = \frac{a}{-2b} = \frac{4.1 \times 10^{-5}}{-2 \times (-4.1 \times 10^{-8})} = 500$ °C

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