THERMO ELECTRICITY

POINTS TO REMEMBER

1. In 1821, seebeck discovered that if two dissimilar metals (or) alloys are joined together to form two junctions, and if these junctions are maintained at different temperatures, an emf is developed and electric current flows in the circuit.This arrangement is called thermo couple and the effect is called seebeck effect and the emf developed is called thermo emf.
2. See beck effect is reversible i.e. if the Junction are interchanged, the direction of current is also reversed.
3. Thermo electric series: In the following list of metals current flows from the metal which comes first in the series to the next at the cold Junction.

   Antimony – Arsenic – Iron – Zinc – Copper – Lead – Brass – Al – Hg – Platinum – Cobalt – Nickel – Constantan – Bismuth.

   Greater the separation between the metals greater the thermo emf.(i.e.) thermo emf will be maximum for a thermo couple made up of Antimony and Bismuth.
4. The direction of current will be from copper to iron at the hot Junction in Cu – Fe thermocouple.
5. In the case of antimony-bismuth thermocouple, at the cold junction, current flows from antimony to bismuth.
6. Thermo emf depends on temperature difference between Junctions and the material of the metals.
7. When the cold junction is at 0°C and hot junction is at t°C, the thermo emf developed is given by $e = at + bt^2$ where a and b are constants.
8. Neutral temperature: It is the temperature of hot junction at which thermo emf is maximum . It depends upon the nature of the pair of metals. It is a constant for a given thermo-couple. It does not depend upon temperature of cold junction.

   Temperature of inversion: It is the temperature of hot junction at which thermo emf becomes zero or its sign is just reversed. It depends on the nature of metals and the temperature of cold junction. As temperature of cold junction increases, temperature of inversion decreases. $T_i = -\frac{a}{b}$
9. Temperature difference between neutral temperature and cold junction is equal to the temperature difference between neutral temperature and inversion temperature. $T_n = \frac{T_i + T_c}{2}$
10. Duddell's galvanometer can be used to measure both AC and DC. This is the combination of thermo-couple and a moving coil galvanometer. $\left(\theta \alpha i^2\right)$
11. Peltier Effect :When current passes through a thermo couple having Junctions at the same temperature heat is evolved at one junction and heat is absorbed at the other Junction. This is called Peltier Effect.The Junction which was heated in seebeck effect will now absorb the heat and at the other Junction heat is evolvedIf the direction of current is reversed, the heat absorption or heat evolution will be interchanged. Hence Peltier effect is reversible
12. The amount of heat absorbed or evolved at any Junction of a thermo-couple is proportional to the charge passing through the couple. $Q \alpha q$

$Q = \pi q = \pi \, it$ Joule (or) $\pi = \frac{\theta}{it}$ Where π is called Peltier co-efficient.

Unit : J/col or J/amp-sec (or) Volt..

Peltier coefficient depends on

a) The nature of the metals forming the Junctions.

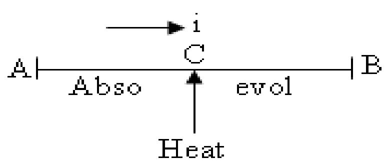
b) Temperature of the Junction.

13. Joule's Heating effect: When ever current passes through a conductor heat is produced in it. This is called Joules heating effect of electric current. If the direction of current is reversed, then also heating effect is produced. Hence Joules effect is irreversible. The amount of heat produced in a current carrying conductor (Q) is proportion to the square of the current (i^2), resistance (R) of the conductor and the time of passage of the current in the conductor $Q = \frac{i^2 Rt}{J}$

When J is called Joules constant or (or) Mechanical equivalent of heat J = 4.2J/cal.

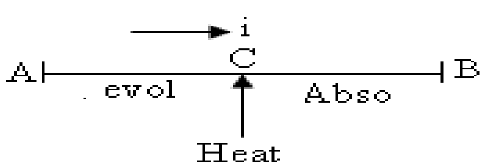
14. Thomson effect: The absorption (or) evolution of heat energy due to the flow of current in an un equally heated conductor is known as Thomson effect. This depends on the direction of current.

15. Thomson effect is positive it heat energy is absorbed along the conductor while current as passing from cold end to hot end of the conductor. On reversing the current direction, heat is evolved from the conductor.



Ex : Copper, Sb, As, Silver, Zinc Cadmium etc.

16. Thomson effect is negative if heat energy is evolved along the conductor while current passes from cold end to hot end of the conductor .On reversing the direction of the current, heat will be absorbed by the conductor.



Ex: Bi, Pt, Fe, Ni, Cobalt.

17. Thomson effect is said to be neither neutral if heat energy is neither absorbed nor evolved on passing the current from either hot end (or) cold end. Ex : Lead

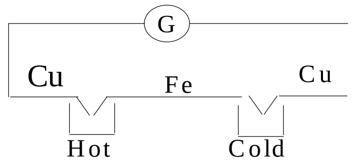
18. Thomson effect is zero for lead.

The amount of heat energy evolved (or) absorbed is given by $H = \sigma$ It $(d\theta)$. Where σ is the Thomson co-efficient.

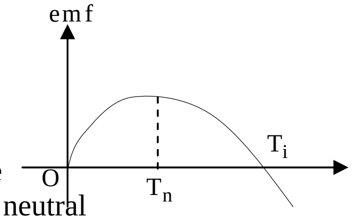
<u>LONG ANSWER QUESTIONS</u>

1. **What is Seebeck effect? Explain the relation between temperature and thermo emf with a neat graph. Define a) temperature of inversion b) neutral temperature. (May2007)**

A. Seebeck effect: when two dissimilar metals are joined to form two junctions and if the junctions are maintained at two different temperatures an emf is generated and current flows through the circuit. This effect is known as seebeck effect. The current flowing through the circuit is called thermo electric current and the e.m.f is called thermo e.m.f.



Relation between thermo emf and temperature: The graph showing the variation of thermo emf with the temperature of the hot junction, while the temperature of cold junction is kept at 0^0C is parabola as shown in figure.



As the temperature of the hot junction increases, the thermo emf also increases and becomes maximum at a temperature (T_n) called neutral temperature. This neutral temperature is constant for a given thermocouple. When the temperature of hot junction is further increased beyond the neutral temperature the thermo e.m.f. starts decreasing. At a particular temperature called temperature of inversion (T_i) it becomes zero.

Beyond the temperature of inversion the thermo e.m.f. reverses its direction. The temperature of inversion depends upon the temperature of cold junction.
In a thermocouple when junction temperature difference is gradually increased the thermo e.m.f. will also be changed gradually. The e.m.f will follow the equation $E = at + bt^2$ which is the equation of a parabola.
Here 'a' and 'b' are constant for a given thermo couple called seebeck constants.
Neutral temperature T_n : The temperature of the hot junction ,for which thermo e.m.f through the circuit is maximum called neutral temperature for the thermo couple.

If thermo e.m.f. $E = at + bt^2$ then for that thermocouple neutral temperature $T_n = \frac{-a}{2b}$.

Inversion Temperature (T_i) : The temperature of the hot junction at which the direction of thermo e.m.f. is reversed in a thermo couple is called inversion temperature.

If thermo e.m.f. of a thermocouple $E = at + bt^2$, then its inversion temperature $T_i = -\frac{a}{b}$

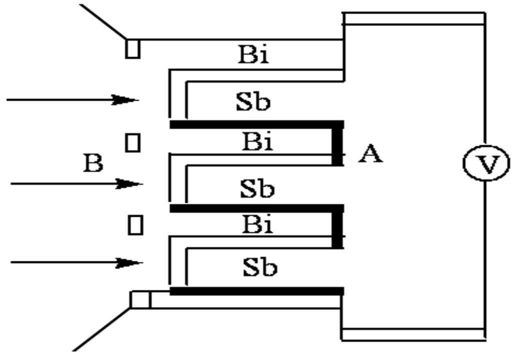
2. Write in detail the applications of thermocouple?

A. a) Thermoelectric thermometer: when the temperature of cold junction of a thermocouple is kept constant and the other junction is heated, it is observed that the thermo e.m.f is directly proportional to the difference of junction temperature upto a limit. The voltmeter in the circuit can be calibrated within this limit, so that the reading directly gives the hot junction temperature. The thermocouple used depends on the range of temperature to be measured. This voltmeter with thermocouples are called thermometers.

Advantages: 1) it is used to measure temperature accurately upto 0.025^0C, 2) it's junctions are very sharp, so they can be used to detect the temperatures 0of minute parts of even small insects, 3) it is used to measure quick changes in temperature.

b) Thermopile: Thermocouple is used to measure heat radiation.
Description: To increase the sensitiveness of thermocouple, a number of couples are joined in series, and in order to reduce the resistance, several thick bars of antimony and bismuth, forming a thermocouple are used to construct thermopile. The ends of the thermopile are

connected to a galvanometer of which the resistance is preferably equal to the thermopile.



One set of the end A, is covered with a brass cap to maintain the temperature of these junctions constant. The junctions on other side 'B' are coated with lamp black and exposed to heat radiation.

<u>Working:</u> when side 'B' is exposed to heat radiation a thermo e.m.f is developed. It is measured by the voltmeter. The e.m.f developed is proportional to the radiation energy incident on B. by using thermopile temperature difference can be measured easily and accurately up to 0.001^0C.

a) <u>Duddell's thermo galvanometer:</u> Thermo galvanometer was designed by duddell. It is used to measure very small currents of the order of micro amperes.

Description: It is combination of moving coil galvanometer and a thermocouple. It consist of a single loop of copper wire. At the free ends of the copper wire antimony (Sb) an bismuth(Bi) are attached as shown in the fig. the lower ends of Sb and Bi are soldered at'B'. A is the cold junction and B is the hot junction. This arrangement is suspended in between the poles N,S of a circular magnet by a phosphor-bronze suspention fibre. A small circular mirror M is attached to the wire. A heater wire 'H' is arranged very nearer to the junction 'B'.

<u>Working:</u> The current to be measured is passed through the heater wire H. Heat produced in the wire heats the junction 'D' thereby producing thermo e.m.f. Then thermoelectric current flows through Bi-Sb thermocouple. So the loop acts as a magnetic shell in the magnetic field, hence it will deflect. Deflection is measured using lamp and scale arrangement. The deflection (θ) of the loop directly proportional to the heat produced in the heater wire H.

$\theta \propto H$

According to joules law $H \propto i^2$

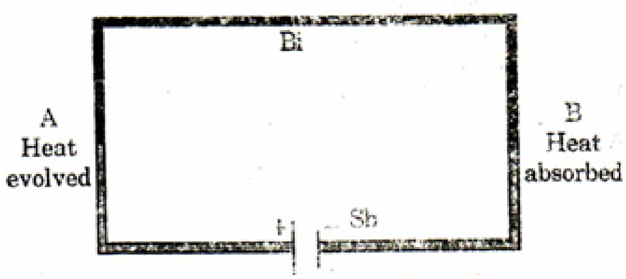
So, we can write $\theta \propto i^2$

As heat produced in the heater wire is independent of direction of current. So, the thermo galvanometer is used to measure both AC. and D.C.

3. Explain Peltier effect and define Peltier coefficient. Distinguish between Peltier heat and joules heat.?

A. <u>Peltier effect:</u> When current is passed through the junction of two dissimilar metals, energy is absorbed or liberated at the junctions in the form of heat. This is called peltier effect. If the current direction is reversed, absorption or liberation of heat energy is also revesed. Hence, peltier effect is a reversible effect.

When current passes through the junctions of thermocouple then heat energy is absorbed at one junction and heat energy is released at another junction. This effect is known as peltier effect.



Peltier effect is a reverse process of seebeck effect. In the case of Antimony-bismuth thermocouple, a current is passed from Sb to Bi, by connecting a battery. Then, heat is liberated at the junction A and absorbed at the junction B. here, heat is liberated at that junction (A) which corresponds to the cold junction in seebeck effect. Peltier effect is converse of Seebeck effect. If a charge q is passed through the junctions of two metals then the amount of heat absorbed or liberated at the junction is $Q \propto q \Rightarrow Q = \pi q = \pi it$
where i is the current passing for t seconds) π is a called peltier coefficient.
If i=1 Amp ,t=1 sec, q=1 coul, then $\pi = Q$

Peltier coefficient(π) : it is defined as the amount of heat energy absorbed or released at the junctions of a thermocouple when a charge of one coulomb passes through them.

Peltier coefficient $\pi = \frac{Heat\ energy\ absorbed\ or\ released}{Charge\ flowing\ through\ the\ junction} = \frac{Q}{q}$

Peltier coefficient changes with temperature of the junction in Kelvin scale.
S.I. unit of peltier coefficient, $\pi = Joule/coulomb\ or\ volt$.
π is numerically equal to the contactpotential (V) difference at the junction of the two metals, π is also called as peltier e.m.f. π is not a constant.
π depends on (i) nature of the metals used and (ii) absolute temperature (t) of the junction.

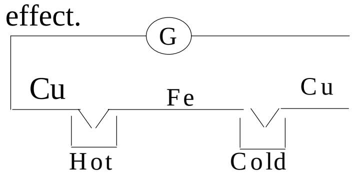
Peltier effect	Joule Effect
This is reversible	This is not reversible
Heat may be absorbed (or) evolved	Heat is always evolved
Heat energy is proportional to the current passing through the conductor. ($H \alpha i$)	Heat is proportional to the square of the current passing through the conductor.($H \alpha i^2$)
This is observed only at the Junctions	This is observed throughout the length of the conductor

SHORT ANSWER QUESTIONS

1. Explain the seebeck effect with a neat diagram.?

A. If two dissimilar metallic wires are joined together to form two junctions then it is called thermocouple.

<u>Seebeck effect:</u> When a temperature difference is maintained between the junctions of a thermocouple then e.m.f. is developed across the junctions and current flows in the circuit. This effect is known as seebeck effect.



Explanation: Let a thermocouple is formed with iron(Fe) and copper(Cu) wires. When one junction is heated by keeping the other at room temperature, junction temperature difference is created. At room temperature, every conductor contains some free electrons available for conduction. The free electrons available per unit volume are called electron density. Different conductors will have different electron densities. When junction temperature difference is maintained, these electrons will diffuse from higher density material to lower density material just like diffusion of gases. So e.m.f. will develop across the junctions and current will flow in the circuit.

2. **What are petlier and Thomson effects? Define their co-efficients? (March2010,May2009, March2009)**

A. Petlier effect: When current passes through a thermo couple having Junctions at the same temperature heat is evolved at one junction and heat is absorbed at the other Junction. This is called Peltier Effect.

Petlier effect is a reverse process of seebeck effect.

Petlier coefficient (π): It is defined as the amount of heat energy absorbed or released at the junctions of a thermocouple when a charge of one coulomb passes through them.

Unit: Joule/coulomb.

Peltier coefficient $\pi = \dfrac{Heat\,energy\,absorbed\,or\,released}{Charge\,flowing\,through\,the\,junction} = \dfrac{Q}{q}$

Petlier coefficient changes with temperature of junction in Kelvin scale.

Thomson effect: When current flows through an unequally heated conductors, heat energy is liberated or absorbed throughout the metals of a thermocouple apart from its junctions. This is known as Thomson effect. It is a reversible effect.

Thomson coefficient (σ): It is defined as the amount of heat energy absorbed or released when a current of 1 ampere passes through the conductors per second when a temperature difference of $1^0 C$ is maintained between the conductors.

Thomson co-efficient $(\sigma) = \dfrac{Heatenergyabsorbedorrelased}{Current \times Temparaturedifference} = \dfrac{Q}{it\,dT}$

Unit: Joule/coulomb-K

3. **Describe how thermocouple can be used for measuring temperatures?**

A. When the temperature of cold junction of a thermo-couple is kept constant and the temperature of other junction is increased, it is observed that the thermo emf is directly proportional to the difference of junction temperature up to a certain limit. A voltmeter can be calibrated within this limit so that the reading directly gives the temperature of hot junction. Different thermocouples can be used depending on the range of temperature to be measured. This voltmeter with thermocouple is called thermoelectric thermometer.

Thermoelectric thermometers are used.

(i) to measure temperature are used.

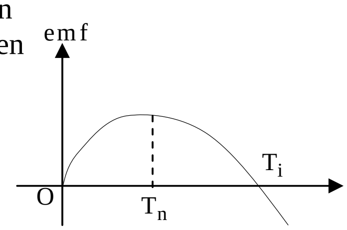
(ii) to measure temperature accurately upto $0.025^0 C$

(iii) to detect temperatures of small insects.

4. **Explain how thermo e.m.f varies with temperature in a thermocouple.?**

A. As temperature of hot junction increases, thermo e.m.f increases to a maximum value and then decreases to zero. The graph of thermo e.m.f. versus temperature of hot junction is a parabola as shown in figure.

keeping cold junction at 0^0C, the temperature of hot junction is slowly increased. For small temperature difference between two junctions, the thermo e.m.f. is directly proportional to the difference of temperature. If e is the thermo e.m.f., and 'T' is the temperature difference.



Then $e = aT + bT^2$, which is parabolic in nature.

The temperature of hot junction at which thermo e.m.f. is maximum is known as neutral temperature (T_n).

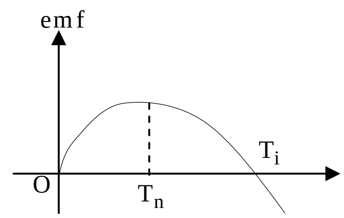
The temperature of hot junction at which the thermo e.m.f reverses is known as inversion temperature(T_i).

The neutral temperature is independent of temperature of cold junction, where as inversion temperature depends on temperature of cold junction.

5. Explain neutral and inversion temperature with the help of the graph between Thermo emf and the temperature of hot junction.? (June2010)

A. In a thermocouple when junction temperature difference is gradually increased the thermo e.m.f. will also gradually change. The e.m.f. will follow the equation $\varepsilon = aT + bT^2$. When a graph is plotted between junction temperature difference and junction e.m.f. it will be as shown.

<u>Neutral temperature</u>(T_n): The temperature of the hot junction for which the thermo emf through the circuit is maximum is called neutral temperature for the thermo couple. If thermo e.m.f $E = at + bt^2$, then for that thermocouple neutral temperature $T_n = \frac{-a}{2b}$. If a thermocouple is heated beyond neutral temperature then thermo e.m.f will gradually decrease.

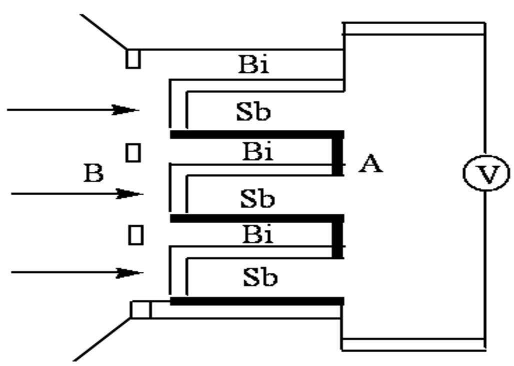


<u>Inversion Temperature</u> (T_i): The temperature of the hot junction at which the direction of thermo emf is reversed in a thermo couple is called inversion temperature. $T_i = -\frac{a}{b}$

6. Write short notes on working of thermopile? (March2011)

A. <u>Thermopil:</u> This device is used to detect the thermal radiation.

<u>Principle:</u> This is based on the principle that black bodies are the perfect absorbers of thermal radiations.



<u>Description:</u> A thermopile consists of thermocouples connected in series which are in turn connected to a galvanometer. One set of junctions (Sb) is blackened and other set of junctions are protected from heat.

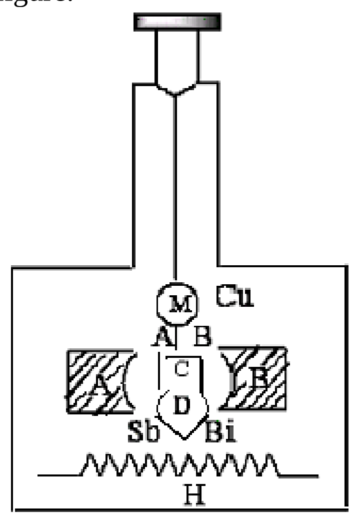
Working: When thermal radiation falls on the junction of a thermocouple coated with lamp black it will absorb heat energy and is heated. So junction temperature difference is produced. Due to seebeck effect, current flows through the thermopile.
A voltmeter is connected to the thermopile which can read the current directly.

The deflection produced in the voltmeter is proportional to the intensity of incident radiation. Using thermopile, temperature differences of order of 0.001^0C can be detected.

7. Explain construction and working of Duddell's thermo galvanometer.

A. Duddell's thermo galvanometer: It is a combination of moving coil galvanometer and a thermocouple.

Description: It consists of a single loop of copper wire AB. To the lower ends of the loop two strips of antimony (Sb) and Bismuth (Bi) are attached. The lower ends of these strips are soldered at D. A heater coil H is placed just below the Sb-Bi junction (D). now D acts as the hot junction and C is the cold junction. The whole arrangement is suspended between the poles NS of a circular magnet by a phosphor bronze suspension. A small circular mirror M is attached to this suspension. This is as shown in figure.



Working: The current to be measured is passed through the heater wire 'H'. Heat produced in this wire heats up the junction D and hence thermo e.m.f is developed and thermo current flows through Sb-Bi thermocouple. The deflection is measured with the help of a lamp and scale arrangement and the instrument is calibrated directly for measuring currents. Here heat produced Q is proportional to the square of the current in it. $Q \propto i^2$ Where i is the current to be measured.Hence deflection $\theta \propto i^2$

Since the heat produced in a resistance is independent of direction of current, this device is used to measure both AC and DC .It is particularly suitable to measure high frequency oscillating currents of the order of microamperes.

8. Explain how thermo e.m.f is caused and what are the factors on thermo e.m.f generated depends upon?

A. Origin of thermo e.m.f: In metallic conductors like Cu or Fe free electrons move at random and exert pressure. The number of free electrons per unit volume is called electron density(η_e). η_e is different for different metals and at the same temperature η_e is more in r iron than in copper.

If two metals like Fe and Cu are joined, then free electrons diffuse from the metal of higher electron density to the metal of lower electron density. As a result, one metal (Fe) is charged positively and the other (Cu) is charged negatively at the junction.

Thus a fixed potential difference is developed across the junction. Which is called contact potential or junction potential. This contact potential depends on temperature. This contact potential is more at the hot junction than that at the cold junction . Hence is thermo current flows in the thermocouple.

9. what is the thermo electric series? Explain its importance.?

A. Thermo electric series: In the following list of metals current flows from the metal which comes first in the series to the next at the cold Junction.

Antimony – Arsenic – Iron – Zinc – Copper – Lead – Brass – Al – Hg – Platinum – Cobalt – Nickel – Constantan – Bismuth.

Importance: Greater the separation between the metals greater the thermo emf.(i.e.) thermo emf will be maximum for a thermo couple made up of Antimony and Bismuth.

10. What are thermoelectric thermometers? What are their advantages?

A. Thermo electric thermometer: This is based on the principle of seebeck effect. Different thermo couples are to be selected for measuring different ranges of temperatures.

Examples:

1. Copper-constantan couple: $-200^0 C\, to\, 300^0 C$
2. Iron-Nickel couple : $300^0 C\, to\, 600^0 C$
3. Nickel-Chromium couple : $600^0 C\, to 1000^0 C$
4. Platinum-Platinum rhodium couple : $upto 1600^0 C$
5. Copper-gold iron alloy : $-200^0 C$

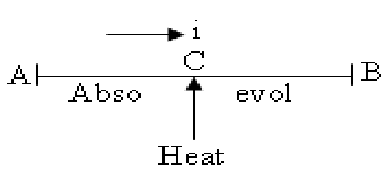
Advantages:

1) Wide range of temperature measurement $\left(-200^0 C\, to 1600^0 C\right)$.
2) Temperatures can be measured accurately up to $\frac{1}{40^0} C$.
3) Thermal capacity of the hot junction is very small. Hence, quickly varying temperatures also can be measured.
4) As the hot junction is very sharp and small in size, the temperatures of small insects also can be measured.
5) Temperatures of furnaces also can be measured.
6) Temperatures of wild animals also can be measured (from a distance).

11. Explain Thomson effect and define Thomson coefficient.?

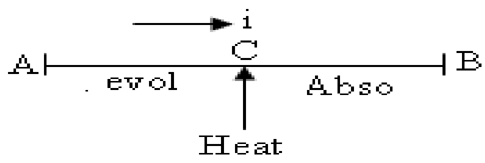
A. Thomson effect :The absorption (or) evolution of heat energy due to the flow of current in an un equally heated conductor is known as Thomson effect. This depends on the direction of current.

a. Thomson effect is positive it heat energy is absorbed along the conductor while current as passing from cold end to hot end of the conductor. On reversing the current direction, heat is evolved from the conductor.



Ex : Copper, Sb, As, Silver, Zinc Cadmium etc.

b. Thomson effect is negative if heat energy is evolved along the conductor while current passes from cold end to hot end of the conductor .On reversing the direction of the current, heat will be absorbed by the conductor.



Ex: Bi, Pt, Fe, Ni, Cobalt.

c. Thomson effect is said to be neither neutral if heat energy is neither absorbed nor evolved on passing the current from either hot end (or) cold end. Ex : Lead

Thomson effect is zero for lead.

d. The amount of heat energy evolved (or) absorbed is given by $H = \sigma$ It $\left(d\theta\right)$.

Where σ is the Thomson co-efficient.

Thomson coefficient(σ): It is defined as the amount of heat energy absorbed or released when a current of 1 Ampere passes through the conductors per second when a temperature difference of 1^0C is maintained between the conductors.

Thomson coefficient $(\sigma) = \dfrac{Heat\, energy\, absorbed\, or\, released}{Current \times Temparature\, difference} = \dfrac{Q}{it\, dT}$

Unit : Joule/coulomb-K.

Very Short Answer Questions

1. What are Seebeck effect and Peltoer effect?

A. Seebeck effect: When two dissimilar metals are joined to two junctions and if the junctions are maintained at two different temperatures, an e.m.f is developed in the circuit and the current flows the circuit. This effect is known as Seebeck effect.

Peltier effect: When current passes through the junctions of thermocouple then heat energy is absorbed at one junction and heat energy is released at another junction. This effect is known as peltier effect.Peltier effect is a reverse process of Seebeck effect.

2. What is a thermocouple? Write one of its uses?(March2011)

A. A pair of wires dissimilar metals forming a closed circuit with two junctions and producing electric current on maintaining temperature difference between the junctions is called thermo couple.

Uses: A thermo couple is used to measure the temperature accurately upto 0.025^0C.

3**. Define neutral and inversion temperatures?**

A. Neutral temperature: The temperature of hot junction for which thermo e.m.f becomes maximum is called neutral temperature.

Inversion temperature: The temperature of hot junction for which thermo e.m.f becomes zero and the reversal of the thermo e.m.f takes place is called inversion temperature, keeping the cold junction is at 0^0C.

4. What is a thermopile and what is its use?

A. The device which consists of series of thermocouples is called thermopile. It is used to detect heat radiation.

5. In duddell's thermo-galvanometer, how amount of heat and deflection are related with current?

Sol: In duddell's thermo-galvanometer, the amount of heat is directly proportional to heat produced. $\theta \propto H$; But $H = i^2\, rdt \Rightarrow \boxed{\theta \propto i^2}$

Hence deflection is proportional to square of current.

6. Define Petlier coefficient and Thomson coefficient?(Mar-03, 06)(may 06)

A. Petlier coefficient: (π): It is defined as the amount of heat energy absorbed or released at the junctions of a thermocouple when a charge of one coulomb passes through them.

Unit: Joule/coulomb

Petlier coefficient $\pi = = \frac{Heat\ energy\ absorbed\ or\ released}{Charge\ flowing\ through\ the\ junction} = \frac{Q}{q}$

Petlier coefficient changes with temperature of junction in Kelvin scale.

Thomson coefficient (σ): It is defined as the amount of heat energy absorbed or released when a current of 1 ampere passes through the conductor per second when a temperature difference of $1^0 C$ is maintained between the conductors.

Thomson Coefficient $(\sigma) = \frac{Heat\ energy\ absorbed\ or\ released}{current \times Temperature\ difference} = \frac{Q}{it\ dT}$

Unit: Joule/coulomb-K.

7. What are units of petlier coefficient and Thomson coefficient?

A. 1) petlier coefficient (π) = Joule/coulomb or volt.

2) Thomson coefficient (σ) = Joule/coulomb/K or volt/ K.

8. How does the thermo e.m.f vary with temperature in a thermocouple? What is the nature of the graph?

A. As the temperature of the hot junction increases, thermo e.m.f will also increase upto some limit called neutral temperature.

After the neutral temperature thermo e.m.f. decreases, with increasing temperature and becomes zero at inversion temperature.

Nature of the graph between temperature of the hot junction and thermo e.m.f is a parabola.

9. Write the names of temperature at which thermo e.m.f of a thermocouple becomes maximum and zero?

A. The temperature at which thermo e.m.f of a thermo-couple is maximum is called neutral temperature.

The temperature at which thermo e.m.f of a thermo-couple is minimum is called inversion temperature.

10. What is thermo electric series? Which thermo couple is widely used?

A. In the following list of metals current flows from the metal which comes first in the series to the next at the cold Junction.

Antimony – Arsenic – Iron – Zinc – Copper – Lead – Brass – Al – Hg – Platinum – Cobalt – Nickel – Constantan – Bismuth.

Antimony (sb) and Bismuth (Bi) thermocouple is widely used.

11. What instrument is used for measuring heat radiation? Write its principle?

A. For measuring heat radiation a thermopile is used.

A thermopile consists of number of thermocouples connected in series so that two junctions are formed with all the thermocouples. One set of junctions are coated with lamp black and the other set is covered to protect from heat radiation.

12. State the relation among cold junction temperature (T_0) neutral temperature (T_n) and inversion temperature (T_i).

A. The difference in the temperature of cold junction (T_0) and the neutral temperature (T_n) is equal to the difference of the temperature of inversion (T_i) and the neutral temperature (T_n).

$$\therefore T_n - T_c = T_i - T_n \quad \text{(or)} \quad 2T_n = T_c + T_i$$

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

13. Does neutral temperature depends on cold junction temperature? If not, on what factors does it depend?

A. Neutral temperature is constant for a given pair of dissimilar metals. It depends only on the nature of the metals used in a thermocouple.

Ex: For iron-copper - $270^0 C$ For copper-nickel- $390^0 C$.

SOLVED PROBLEMS

1. A coppe–constant thermocouple is having thermo emf $40\mu V$ for a temperature difference of $1^0 C$. The same thermocouple is used to measure the current flow of $10^{-6} A$ through a galvanometer having resistance of 100Ω. Find the minimum temperature difference to be measured using this thermocouple.?

Sol: The resistance of the galvanometer $= 100\Omega$

The current measured through the galvanometer $= 10^{-6} A$

The emf developed = current x resistance $= 10^{-6} \times 100V - 100\times 10^{-6} V$.

For $40\times 10^{-6} V$ thermo emf, the temperature difference $= 1^0 C$

So, for 100×10^{-6} V thermo emf, the temperature difference $= \frac{100\times 10^{-6}}{40\times 10^{-6}} \times 1^0 C = 2.5^0 C$

The minimum temperature difference measured using this thermo couple $= 2.5^0 C$

2. In a thermocouple the cold junction is at $20^0 C$ and the neutral temperature is $270^0 C$. Find the inversion temperature.?

Sol: $T_n = 270^0 C$

$T_c = 20^0 C$

$T_n = \frac{T_i + T_c}{2} \quad \Rightarrow \quad T_i = 520^0 C$

3. If θ is the temperature of the hot junction of a thermocouple and the cold junction is at $0^0 C$ then its thermo emf is $E = a\theta + b\theta^2$.Find the neutral and inversion temperature of Ni – Cu thermocouple is a $= 16.3\times 10^{-6} V/^0 C$ and $b = -0.021\times 10^{-6} V/^0 C^2$

Sol: a) At neutral temperature the thermo emf becomes maximum.

$E = a\theta + b\theta^2$

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

At $\theta = T_n, \frac{dE}{d\theta} = 0 \quad \Rightarrow T_n = \frac{-a}{2b} = \frac{-16.3\times 10^{-6}}{2\times -0.021\times 10^{-6}} = 388.1^0 C$

b) At inversion temperature $\theta = T_i$, thermo emf, E = 0

$E = a\theta + b\theta^2 \quad$ Or $\quad 0 = aT_i + bT_i^2$

$\therefore T_i = \frac{-a}{b} = 2T_n = 776.2^0 C$

4. **Antimony –bismuth thermoco uple generates a thermo emf of $100\mu V/^0C$ when the cold junctions is at 0^0C. A micro ammeter of resistance 100Ω is connected in the circuit of Sb- Bi thermocouple. If the least count of the micro ammeter is $1\mu A$ find the minimum temperature difference it can measure. (neglect the resistance of Sb- Bi thermocouple)**

Sol: Sb-Bi thermocouple generates a thermo emf of $100\mu V$ for one degree difference between the cold and hot junctions.

Least count of an instrument is the smallest value it can measure. Hence the smallest current it can measure is $1\mu A$. Then the smallest potential difference it can measure, V = IR where R is the resistance of the galvanometer.

$V = 1\times 100 = 100\mu V$.

$$\text{Required temperature difference} = \frac{\text{Minimum V}}{\text{Thermo emf per degree difference}} = \frac{100}{100} = 1^0C$$

<u>UNSOLVED PROBLEMS</u>

1. **A Copper-constant thermocouple is having thermo e.m.f. of $50\mu V$ for 1^0C temperature difference. The same thermocouple is used to measure the current flow of $10^{-6}A$, through a galvanometer having resistance of 150 ohms. Then find the minimum temperature difference to be measured by using this thermocouple.?**

Sol: $e = 50\mu V/^0C = 50\times 10^{-6}V/^0C$; $i = 10^{-6}\,amp$.

Resistance of the galvanometer e = iR

$e = 10^{-6}\times 150\,\mu V$

$\therefore$ Minimum temperature we can measure

$$T = \frac{150\mu V}{50\mu V}\times 1^0C = 3^0C.$$

2. **The neutral temperature of a thermocouple is 180^0C. What is the inversion temperature, when the cold junction is at 20^0C?**

Sol: $T_n = 180^0$; $T_c = 20^0C$; T_i = ?

But , $T_n = \dfrac{T_c + T_i}{2}$

$\therefore T_i = 2\times 180 - 20 = 340^0C$

3. **The neutral temperature of iron copper thermocouple is 285^0C and cold junction temperature is 0^0C. Find the temperature of inversion? Also find the temperature of inversion, if the cold junction is maintained at 10^0C.**

Sol: a) $T_n = 285^0C$; $T_c = 0^0C$; T_i = ?

$$T_n = \frac{T_i + T_c}{2} \Rightarrow T_i = 2\times 285 = 570^0C$$

b) $T_c = 10^0C$

$\therefore T_i = 2\times 285 - 10 = 570 - 10 = 560^0C$

4. **The temperature of inversion of iron-copper thermocouple is 590^0C and cold junction temperature is 0^0C. What is the neutral temperature?**

Sol: $T_i = 590^0C$; $T_c = 0^0C$

$$T_n = \frac{T_i + T_c}{2} \Rightarrow T_n = \frac{590}{2} = 295^0C$$

6. **The neutral temperature of copper-nickel thermocouple is 390^0C and cold junction thermocouple at 0^0C, find the temperature of inversion for it.(March2008)**

Sol: $T_n = 390^0C$; $T_c = 0^0C$

$T_n = \frac{T_i + T_c}{2} \Rightarrow T_i = 390 \times 2 - 0 = 780^0C$

7. **The inversion temperature of iron-copper thermocouple is 540^0C and the cold junction is at 0^0C. What is its neutral temperature.(June2005)**

Sol: $T_i = 540^0C$; $T_c = 0^0C$; $T_n = ?$

$T_n = \frac{T_i + T_c}{2} = \frac{540+0}{2} = 270^0C$

8. **The neutral temperature of Ni-Cu thermocouple is 390^0C. Find the inversion temperature, when its cold junction is at (i) 10^0C and (ii) 20^0C.**

Sol: $T_n = 390^0C$ and $T_n = \frac{T_i + T_c}{2}$

i) $T_c = 10^0C$

$T_i = 770^0C$

ii) $T_c = 20^0C$

$T_i = 760^0C$

8. **The seebeck e.m.f. of a thermocouple, keeping the cold junction temperature at 0^0C is given by $E = aT + bT^2$.Find the neutral and inversion temperature in terms of the constants a and b. ?**

Sol: $e = aT + bT^2$

Cold junction temperature $T_c = 0$

At neutral temperature thermo e.m.f. is maximum. Hence first derivative of $e = aT + bT^2$ is zero.

$\therefore 0 = a + 2bT_n \Rightarrow T_n = \frac{-a}{2b}$

At inversion temperature emf = 0

$$\therefore aT_i + bT_i^2 = 0 \Rightarrow \therefore T_i = \frac{-a}{b}$$

9. **It t is the temperature of the hot junction of a thermocouple and the cold junction is at 0^0C,its thermo emf is $e = aT + bT^2$,find the neutral and inversion temperature of Fe – Cu thermocouple if $a = 13.89\mu$ $\mu V/^0C$ and $b = -0.021\mu V/^0C$.**

Sol: $a = 13.89\mu V/^0C$; $b = -0.021\mu V/^0C$

$T_n = \frac{-a}{2b} = \frac{-1}{2}\left[\frac{13.89}{-0.021}\right] = 330.7^0C$

$T_i = \frac{-a}{b} = -\left[\frac{13.89}{-0.021}\right] = 661.4^0C$

<u>ASSESS YOURSELF</u>

1. In what direction does the current flow in antimony bismuth thermocouple at the hot junction?

A. From Bismuth to Antimony.

2. The neutral temperature of a thermocouple is $180^0 C$. What is the temperature of inversion when the cold junction is at $20^0 C$? (March2007,May2007)

A. $340^0 C$

3. Using thermocouple experiment will it be possible to find the melting point of wax?

A. Yes.

14. An e.m.f of 0.09 V generated when the temperature difference between the junctions of a thermocouple is 75 K. If the temperature of cold junction increases by 15K, find the percentage change of e.m.f?

Sol: Percentage change in e.m.f = $\frac{\Delta E}{E}\times 100 = \frac{\Delta T}{T}\times 100 = \frac{15}{75}\times 100 = 20\%$.

15. A thermocouple produces a thermo e.m.f of $50\mu\, V/^0 C$. A thermocouple of has two junctions at $30^0 C$ and $50^0 C$ respectively. If the thermo e.m.f generated in a thermopile is 100 mV, find the number of thermocouples used in the thermopile.?

A. Thermocouple produced $1^0 C = 50\mu V$

Thermocouple produced for $20^0 C = 1000\mu V$

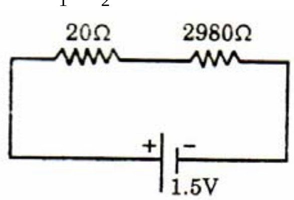
To obtain $1000\mu V$ thermo e.m.f, one thermocouple is required for obtaining 100 mV, the number of thermocouples needed is

$$\frac{\left(100\times 10^{-3}\right)}{1000\times 10^{-6}} = 100$$

16. A cell of constant e.m.f of 1.5 V is connected in series with a potentiometer of length 10m through a resistance of 2980Ω. When one junction of the thermocouple is hot oil and the other inn melting ice, the balancing point is 450cm. if the resistance of potentiometer wire per unit length is $2\Omega / m$, find the thermo e.m.f generated?

A. From the circuit shown, the resistance of potentiometer wire of length 10m is 20Ω.

Then $R_1 : R_2$ =20:2980=1:149 and $V_1 : V_2$ =1:149



$\therefore$ Potential difference across the potentiometer wire $= \frac{1}{150}(1.5) = \frac{1}{100} V$

$\Rightarrow$ thermo e.m.f generated $= \left(\frac{450}{1000}\right)\left(\frac{1}{100}\right) = 45\times 10^{-4}\ V$.

17. **How do you measure rapidly changing temperatures in a circuit?**

A. Rapidly changing temperatures can be measured by a thermocouple accurately.

18. **Using thermo galvanometer, which current can be measured? Ac or dc?**

Sol: Using thermo galvanometer, we can measure both ac and dc.

19**.** **Where will the rate of diffusion of electrons be more in a thermocouple?**

A. The rate of diffusion of electrons in a thermocouple is more at hot junction and less at cold junction.

20. **On what factors, inversion temperature of a thermocouple depends?**

A. Inversion temperature of a thermocouple depends on the nature of the metals and the temperature of cold junction.

21. **If the cold junction temperature of a thermocouple is lowered, what happens to its neutral temperature?**

A. Neutral temperature of a thermocouple is independent of cold junction temperature. Therefore it remains same.