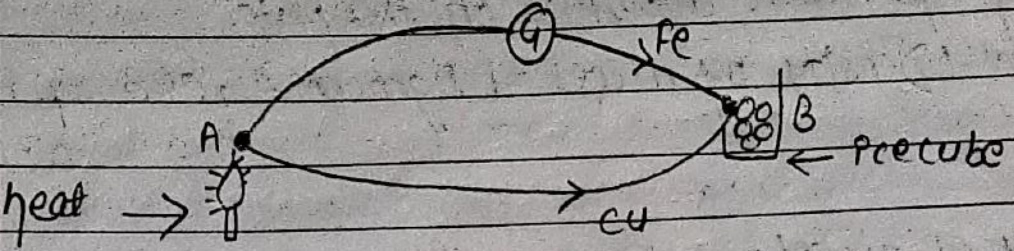
Thermoelectric effect



The production of electricity by keeping the junction of two-dissimilar metals at different temperature is called thermoelectric effect. The electricity generated is called thermoelectricity and the emf ~~occurs~~ across the junction is called thermo emf. the pair of two dissimilar metals used to produce thermoelectricity is called thermocouple.

V.v. Imp long ques — Variation of thermo-emf with temprature

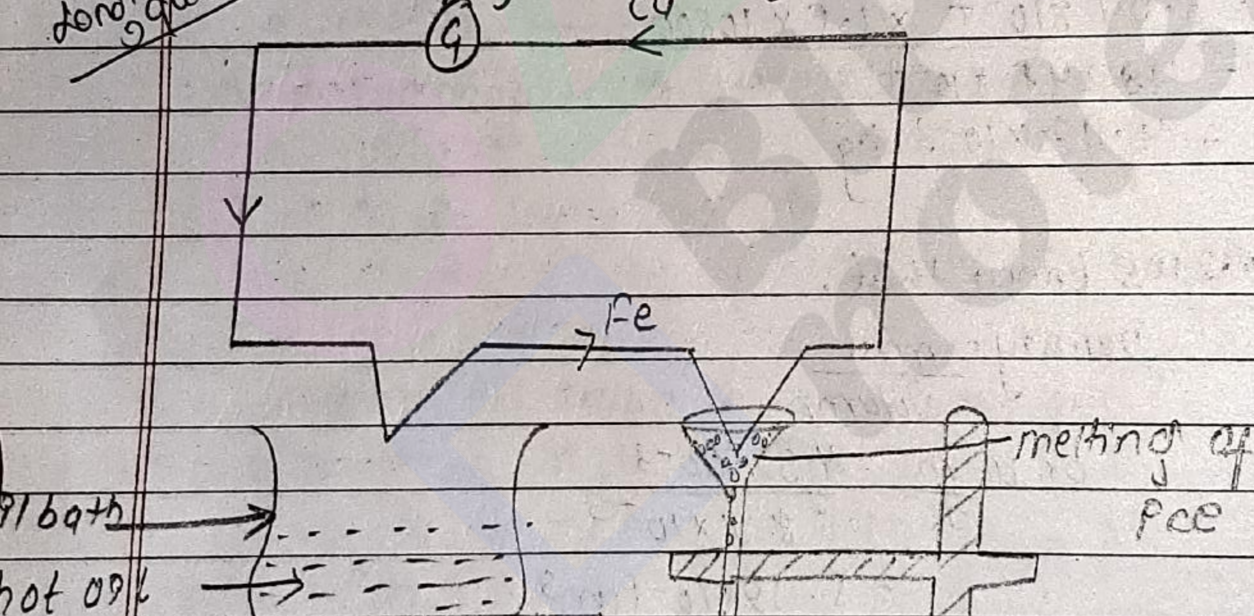


fig :- experiment arrangement for the variation of thermo - emf with temprature.

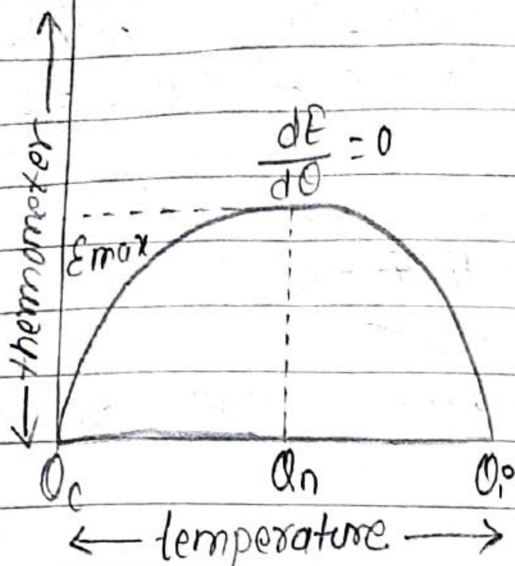


fig-(11)

The experimental arrangement to study the variation of thermo emf with tempn as shown above in which Fe-Cu thermocouple is taken & one junction of which is immersed in a hot oil bath and another junction is kept in melting ice. If the tempn of hot junction is increased the n deflection in the galvanometer is also increased. It means with increase in tempn, the value of thermo emf also increases. The value of thermoemf becomes maximum at a particular tempn called natural temprature (θ_n)

Hence, ~~natural~~ neutral tempn is defined as the temprature of hot junction at which the thermo emf becomes maximum.

If we increase the temprature of hot junction beyond the neutral temprature the value of thermoemf goes on decreasing and becomes zero at a particular temperature called temprature of inversion ~~(...)~~. (θ_i)

Hence, tempⁿ of inversion is defined as the tempⁿ of hot junction at which thermoemf becomes zero and reverse its direction.

From fig (1), it is clear that the value of thermoemf changes parabolically with tempⁿ.
The mathematical expression for the variation of thermoemf with temp can be written as,

$$E = \alpha\theta + \frac{1}{2}\beta\theta^2 \ldots (i)$$

where α & β are called thermoelectric constant and their value depends upon nature of thermocouple used & tempⁿ differences betⁿ hot and cold junction.

Differentiating eqn (i) w.r to 'θ'

$$\frac{dE}{d\theta} = \alpha + \beta\theta$$

If $\theta = \theta_n$ (neutral temprature) then $\frac{dE}{d\theta} = 0$

i.e $\alpha + \beta\theta_n = 0$

$$\theta_n = \left(\frac{-\alpha}{\beta}\right) \text{ --- (ii)}$$

If $\theta = \theta_i$ (tempr of inversion) then $E = 0$

From eqn(i), $0 = \alpha\theta_i + \frac{1}{2}\beta\theta_i^2$

$$\Rightarrow \theta_i\left(\alpha + \frac{1}{2}\beta\theta_i\right) = 0$$

But $\theta_i \neq 0$

i.e $\alpha + \frac{1}{2}\beta\theta_i = 0$

$$\Rightarrow \frac{1}{2}\beta\theta_i = -\alpha$$

$$\Rightarrow \theta_i = 2\left(\frac{-\alpha}{\beta}\right)$$

$$\Rightarrow \theta_i = 2\theta_n \text{ --- (iii)}$$

Also, from fig (b)

$$\theta_n - \theta_c = \theta_i - \theta_n$$

$$\Rightarrow 2\theta_n = \theta_i + \theta_c$$

$$\Rightarrow \theta_n = \frac{\theta_i + \theta_c}{2} \quad \text{---- (iv)}$$

This gives the relation betn neutral temprature of inversion and temprature of cold junction.

If $\theta_c = 0$ then only

$$\boxed{\theta_i = 2\theta_n.}$$

Seeback effect:-

In 1821, Seeback found that the current flows through the thermocouple, when two junctions are kept at different temprature. He found that when one junction is heated and another junction is kept cold, (G) is deflected. He found that in Fe.cu thermocouple, current flows from Fe to cu through cold junction and cu to Fe through hot junction. This effect is called seebeck effect. Hence, seeback effect is defined as generation of thermoelectric current in a thermocouple when its two junction are keept at ~~diffirent~~ different temperature.

Cause of seebeck effect

If two dissimilar metals are made in contact, the free electrons diffuse. from the metal whose work function is low to the metal whose workfunction is high. So, one of the metals is positively charge and other is negatively form in a different of potential across the junction. The ~~emf~~ thus developed across the junction is called contact emf and which depends upon temprature difference betn two junction

5. Due to these contact emf. thermoelectricity is generated in the thermocouple.

If dissimilar metals are made in contact at the junctions, the emf is generated at both junctions in such a way that the direction of one emf is opposite to that other. If both junctions are at the same temprature to each other the net emf becomes zero. Hence, if the junctions are kept at same tempr, no thermoelectricity is generated in a thermo couple.

Peltier effect.

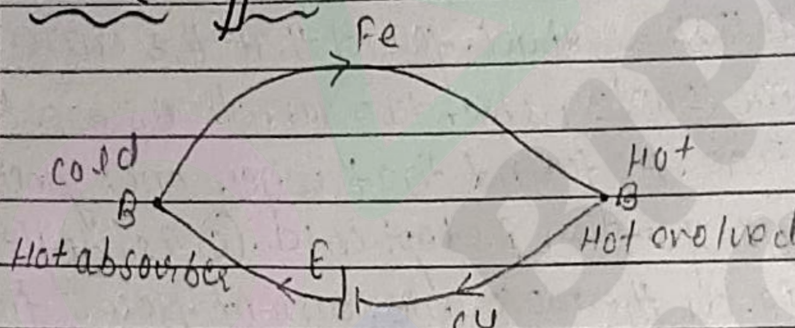


Fig: Peltier effect.

If the junction of thermocouple are kept at constant temp n and a current is passed through the wires of thermocouple as shown in fig. Then, it is found that one of the junctions is heated & another is cooled. This means at one junction, heat is produced & becomes hot junction and at another junction heat is absorbed and becomes cold junction. This effect is called peltier effect.

Hence, peltier effect is defined as the evolution or absorption of heat at two junctions of thermocouple when an electric current is passed through it.

Cause of peltier effect.

When two different metals are joined, contact pd is established at the junctions. This implies that at the junctions, one metal will be at higher potential. In Fe-Cu thermocouple. When current ~~fro~~ flows from thermo couple Fe to Cu i.e higher potential to lower potential, heat is produced at the junction & junction becomes hot. Similarly at junction B, current flows from Cu to Fe i.e from lower potential to higher potential & hence energy is required & which is absorbed from junction & junction becomes cold.

Thomson's effect.

Cold end — current (I) Cu, Ag, Zn → Heat absorbed — Hot end

Cold end — current (I), Fe, Pt, Co — Heat evolved — Hot end

Cold end — current (I) Cu, Ag, Zn ← Heat evolved — Hot end

Cold end — current (I) ← Heat absorbed — Hot end

fig (a) positive Thomson's effect

fig (b) Negative Thomson's effect.

When two ends of the conductor are maintained at different tempr, an emf is established across it. If a steadily current is passed through such unequally heated conductor, heat is absorbed or evolved ~~along~~ along the length of the counductor. This effect is called Thomson's effect.

Hence, Thomson's effect is defined as the evolution or absorption of heat along the length of conductor. When two ends of the conductor are maintained at different tempr & an emf is established across it.

a) Positive thomson's effect.

In some substances like Cu, Ag, Zn heat is evolved when an electric current is passed from hot end to cold end & similarly heat is absorbed when electric current is passed from cold end to hot end as shown in fig (a). This substances is said to have positive thomson's effect.

b) Negative Thomson's effect:-

In some substances like Fe, Pt, Co heat is absorbed when an electric current is passed from hot end to cold end & heat is ~~absorbed~~ evolved when an electric current is passed from cold end to hot end as shown in fig (b). This substances is said to have Negative Thomson's effect.

Note:

In case of lead, heat is neither absorbed nor released when an electric current is passed through it. It means thomson's effect in lead is nil. So, lead is taken as standard metal in thermoelectricity.

Cause of Thomson's effect

When two ends of the conductors are maintained at different temprature, due to diffusion of free electrons from one ends to other end, the two ends will be at different potential i.e one ~~and~~ end will be at higher potential than other end. If steady current is passed through the conductor from hot end to ~~en~~ cold end (i.e higher potential to lower potential) heat is evolved. Similarly, when electric current is passed from cold end to hot end (lower potential to higher potential) energy is required and which is absorbed from the conductor & cooling effect is observed.

S.Q. Differences between peltier's effect & Joule's effect.

Peltier's effect	Joule's effect.
i) It is reversible effect.	i) It is irreversible effect.
ii) Heat is absorbed or released at the junction of two metal	ii) Heat is evolved throughout the conductor.
iii) Heat evolved or produced is directly proportional to the amount of current.	iii) Heat produced is directly proportional to the square of current passing through conductor.
iv) Heat produced or absorbed at the junction of two dissimilar depends upon direction of current.	iv) Heat produced along the length of the conductor is independent of direction of current.

S.Q. Differences betn Thomson's effect & Joule's effect.

Thomson's effect	Joule's effect.
i) It is a reversible effect.	It is a irreversible effect.
ii) Heat is evolved or absorbed.	ii) Heat is always evolved.
iii) Tempr difference is required at the two ends of the conductor.	iii) evo tempr difference is required.
iv) Heat evolved or absorbed depends upon direction of current	iv) Heat evolved along the length of conductor is independent of the direction of current.

v) Heat evolved or absorbed is directly porportional to the amount of current.	Heat evolved along the length of the conductor is directly proportional to the square of current passing through it.

Numerical:-

One junction of a thermocouple is at 0°C ~~at~~ and other at (T' degreecentigrade. The emf is given $E = (20 \times 10^{-6} - 0.02 \times 10^{-6} T^2)$ Vol

find the neutral temperature, temperature of inversion, maximum thermo ~~ee~~ emf.

=) Given,

$E.M.f\ (E) = 20 \times 10^{-6}\ T - 0.02 \times 10^{-6} T^2$ .... (1)

Temprature $(T_C) = 0°C$.

Neutral temperature $(T_n) = ?$

Temperature of Inversion $(T_i) = ?$

Now,

From eqn(i)

$E = 20 \times 10^{-6} T - 0.02 \times 10^{-6} T^2$

Differentiating eqn (i) w.r.t

$$\frac{dE}{dT} = \frac{d}{dt}(20 \times 10^{-6} T - 0.02 \times 10^{-6} T^2$$

$$= 20 \times 10^{-6} - 2 \times 0.02 \times 10^{-6} T$$

$$= 20 \times 10^{-6} - 0.04T \times 10^{-6}$$

Now,

If $T = T_n$ (Neutral temperature) then

$$\frac{dE}{dT} = 0$$

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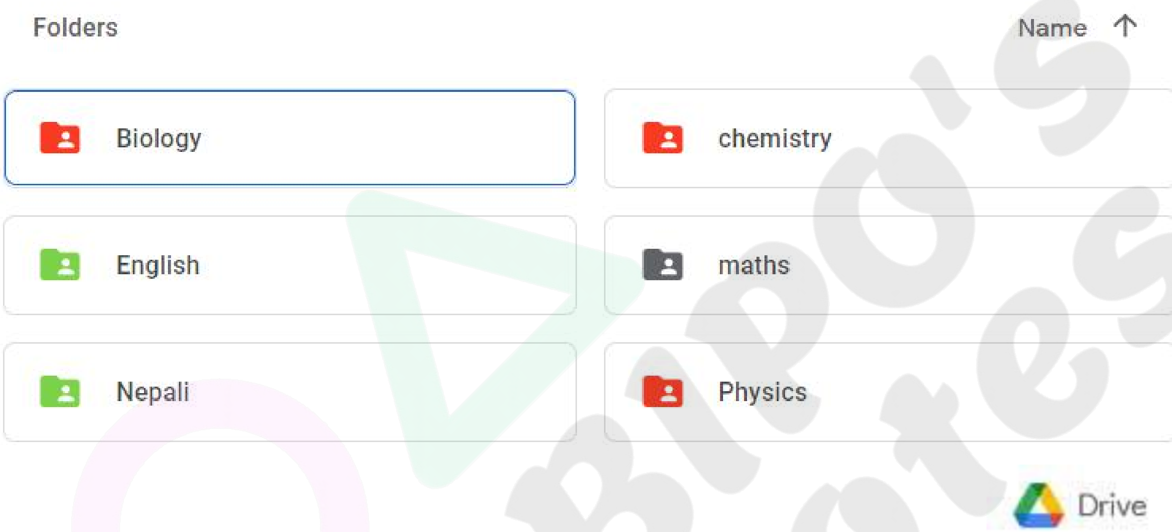
Class 12 complete notes and paper collection.



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