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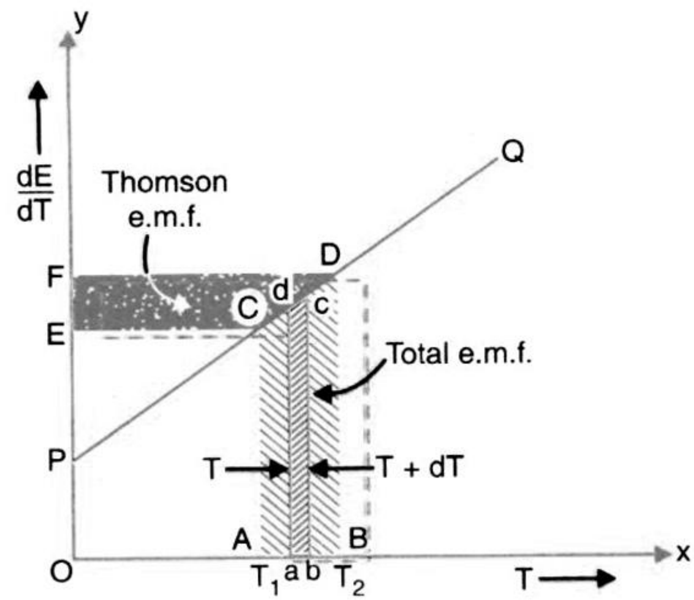
Thermo-Electric Power

Thermo-electric power is defined *as the rate of change of thermo-e.m.f. with temperature.*



This graph showing the relation between thermo-electric power $\frac{dE}{dT}$ and the corresponding absolute temperature T is known as *thermo-electric diagram.* It is always a *straight line* and is known as **thermo-electric power line.** To construct the thermo-electric diagram for any metal lead is taken as the second metal for the thermo-couple because Thomson coefficient for lead is zero.

The relation between the thermo-electric e.m.f. E and the temperature of the hot junction T is expressed as

$E = aT + bT^2$ where a and b are constants for the given thermo-couple.

Thermo-electric power $\frac{dE}{dT}$

$$\frac{dE}{dT} = a + 2bT$$

which is the equation of a straight line. Hence the graph between the *thermoelectric power* $\frac{dE}{dT}$ and the temperature of the hot junction T is a straight line, not passing through the origin

Uses of Thermo-Electric Diagram

Let PQ be the thermo-electric power line for a given metal with respect to lead. Suppose the thermo-couple is maintained with its cold junction at a temperature T_1 and the hot junction at a temperature T_2. Then AC represents the thermo-electric power at T_1 and BD at T_2.

The thermo-electric diagram can be used to find the values of

(*i*) Peltier coefficient

(*ii*) Thermo e.m.f.

(*iii*) Thomson coefficient

(*iv*) Thermo e.m.f. due to a thermo-couple

(*v*) Neutral temperature.

(*i*) **Peltier Coefficient:** The Peltier coefficient π_1 at the temperature of cold junction T_1 is represented by the area $ACEO$ as

$$\pi_1 = T_1 \left(\frac{dE}{dT}\right)_{T_1} = OA \times AC = \text{Area } ACEO$$

Similarly Peltier coefficient π_2 at the temperature of the hot junction T_2 is given by the area $BDFO$ as

$$\pi_2 = T_2 \left(\frac{dE}{dT}\right)_{T_2} = OB \times BD = \text{Area } BDFO$$

$\therefore$ e.m.f. developed due to Peltiers effect is

$$\pi_2 - \pi_1 = \text{Area } BDFO - \text{Area } ACEO$$
$$= \text{Area } ABDFECA \quad ...(i)$$

The Peltier coefficient π is also expressed as $\pi = T\frac{dE}{dT}$

(*ii*) **Thermo-e.m.f.** consider an elementary strip $abcd$ of thickness dT having temperature of the two junctions at T and $(T + dT)$, then

$$\text{Area } abcd = \frac{dE}{dT}dT = dE$$

Hence total e.m.f. developed between the temperatures T_1 and T_2 will be

$$E = \int_{T_1}^{T_2} dE = \text{Sum of the areas of such small strips}$$
$$= \text{Area } ABDC \quad ...(ii)$$

(*iii*) **Thomson coefficient**

The total e.m.f. developed is given by

$$E = (\pi_2 - \pi_1) + \int_{T_1}^{T_2} (\sigma_a - \sigma_b)\,dT$$

$$\therefore \quad \int_{T_1}^{T_2} (\sigma_a - \sigma_b)\,dT = E - (\pi_2 - \pi_1)$$

If the metal A is lead, $\sigma_a = 0$, then

$$\int_{T_1}^{T_2} \sigma_b\,dT = (\pi_2 - \pi_1) - E$$

$= \text{Area } (BDFO - ACEO - ABDC)$

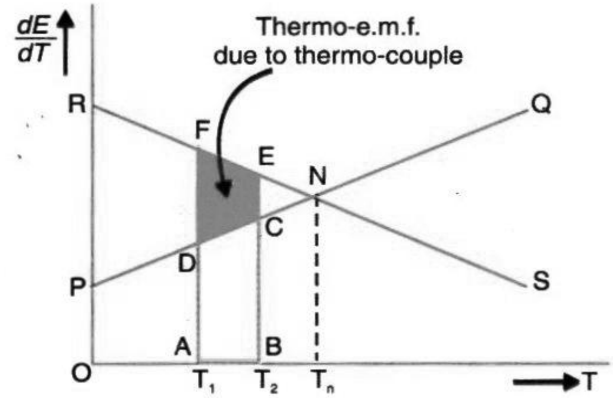
$= \text{Area } CEFD$ ...(*iii*)

Here area *CEFD* represents the e.m.f. produced due to Thomson effect between the temperatures T_1 and T_2 of two junctions.

The value of Thomson coefficient at temperature *T*, the area *CEFD* between the temperature $T_1 = T - ½$ and $T_2 = T + ½$ is measured. As $dT = 1$, this area gives the Thomson coefficient at the temperature *T*.

Thomson coefficient is also expressed as

$$\sigma = T\frac{d^2E}{dT^2}.$$



(*iv*) Thermo-e.m.f. due to thermo-couple. Consider a thermo-couple consisting of two metals *X* and *Y*. Let *PQ* and *RS* be their thermo-electric power lines respectively. The e.m.f. between the absolute temperatures T_1 and T_2 for metal *X* is given by the area *ABCD* and for the metal *Y* by the area *ABEF*.

Therefore, e.m.f. for a thermo-couple consisting of metals *X* and *Y* between the same temperatures T_1 and T_2 will be

$= \text{Area } ABEF - \text{Area } ABCD$

$= \text{Area } DCEF$

(*v*) Neutral Temperature. The point *N* where the two thermo-electric power lines intersect gives the neutral temperature (T_n) for this thermo-couple formed by two metals *X* and *Y*. At this temperature $\frac{dE}{dT} = 0$.