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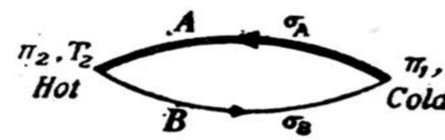
Paper –IV, Group B

Relation between the Thermocouple coefficient

Consider a thermocouple of two metals A and B with their junctions at temperatures T_2 and T_1. The Peltier coefficient at temperature T_1 is π_1, and at temperature T_2 is π_2; and σ_A and σ_B are the Thomson coefficients of A and B. If a current of I ampere passes for t second, then



Energy absorbed due to Peltier effect at the hot junction $= \pi_2 It$

Energy absorbed due to Peltier effect at the cold junction

$$= -\pi_1 It \qquad (-ve \text{ sign, because energy is evolved})$$

Energy absorbed in metal A due to Thomson effect

$$= \left(\int_{T_1}^{T_2} \sigma_A \, dT\right) It$$

Energy absorbed in metal B due to Thomson effect

$$= -\left(\int_{T_1}^{T_2} \sigma_B \, dT\right) It$$

The $-ve$ sign before the integral indicates that current flows from higher to lower temperature.

$\therefore$ Total gain in energy for the complete circuit

$$= \left[(\pi_2 - \pi_1) + \int_{T_1}^{T_2} (\sigma_A - \sigma_B)\, dT \right] It \qquad \ldots(i)$$

The total thermo-EMF produced in the circuit $= E$ volts

$\therefore$ Energy produced $= EIt$ $\ldots(ii)$

$\therefore$ Equating (i) and (ii),

$$EIt = \left[(\pi_2 - \pi_1) + \int_{T_1}^{T_2} (\sigma_A - \sigma_B)\, dT \right] It$$

or

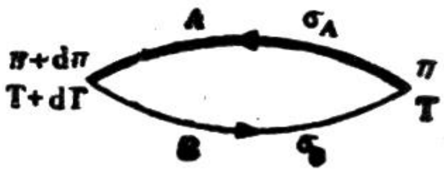
$$E = \pi_2 - \pi_1 + \int_{T_1}^{T_2} (\sigma_A - \sigma_B)\, dT$$

If the two junctions are at a difference of temperature dT and the difference in Peltier coefficient is $d\pi$, then

$$dE = d\pi + (\sigma_A - \sigma_B)\, dT \qquad \ldots(iii)$$

According to the second law of thermodynamics, in a complete reversible process, $\dfrac{H_1}{T_1} = \dfrac{H_2}{T_2}$

H_1 is the heat absorbed at temperature T_1 and H_2 is the heat rejected at temperature T_2.



In this case, the two junctions are at temperatures T and $T+dT$ and a current of I amperes flows for t seconds

Energy absorbed at the hot junction due to Peltier effect.

$$= (\pi+d\pi)\ It \text{ joule} = \frac{(\pi+d\pi)\ It}{J} \text{ cal.}$$

Energy evolved at the cold junction due to Peltier effect

$$= (\pi)\ It \text{ joule} = \frac{\pi It}{J} \text{ cal.}$$

Total energy absorbed due to Thomson effect

$$= [(\sigma_A - \sigma_B)\ dT]\ It \text{ joule}$$

$$= \frac{[(\sigma_A - \sigma_B)\ dT] It}{J} \text{ cal}$$

$\therefore$ Applying the second law of thermodynamics

$$\frac{(\pi+d\pi)It}{J\ (T+dT)} + \frac{[(\sigma_A-\sigma_B)dT]\ I.t}{J(T)} = \frac{\pi It}{JT}$$

$$\frac{\pi+d\pi}{T+dT} - \frac{\pi}{T} + \frac{(\sigma_A-\sigma_B)dT}{T} = 0$$

$$\frac{\pi T + Td\pi - \pi T - \pi dT}{T\ (T+dT)} + \frac{(\sigma_A-\sigma_B)dT}{T} = 0$$

$$[T\ (T+dT) = T^2 \text{ (approx.)}]$$

$$\therefore \qquad \frac{Td\pi}{T^2} - \frac{\pi dT}{T^2} + \frac{(\sigma_A-\sigma_B)dT}{T} = 0$$

$$d\pi - \frac{\pi dT}{T} + (\sigma_A - \sigma_B)\ dT = 0$$

$$d\pi + (\sigma_A - o_B)\ dT = \frac{\pi dT}{T}$$

But, $\quad d\pi + (\sigma_A - \sigma_B)\ dT = dE$ from equation (*iii*)

$$\therefore \qquad dE = \frac{\pi dT}{T}$$

$$\pi = T\ \frac{dE}{dT}$$

where $\dfrac{dE}{dT} = P =$ the thermo-electric power

$\therefore$ Peltier coefficient = (Absolute Temp.) $\times$ (Thermo-electric Power).