Thermoelectric Effect

The phenomenon in which electrical energy is produced by means of thermal energy is called thermoelectric effect.
It involves three effects: Seebeck effect, Peltier effect and Thomson's effect.

1. Seebeck effect

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. The emf thus developed in the circuit is called thermo emf and the corresponding current is called thermoelectric current.

Thermocouples.

A couple of wires of dissimilar metals forming a loop and producing thermoelectricity is called thermocouple.

In iron-copper thermocouple, current flows from iron to copper at the cold junction. The direction of current flow changes if heating and cooling of the junction are reversed.

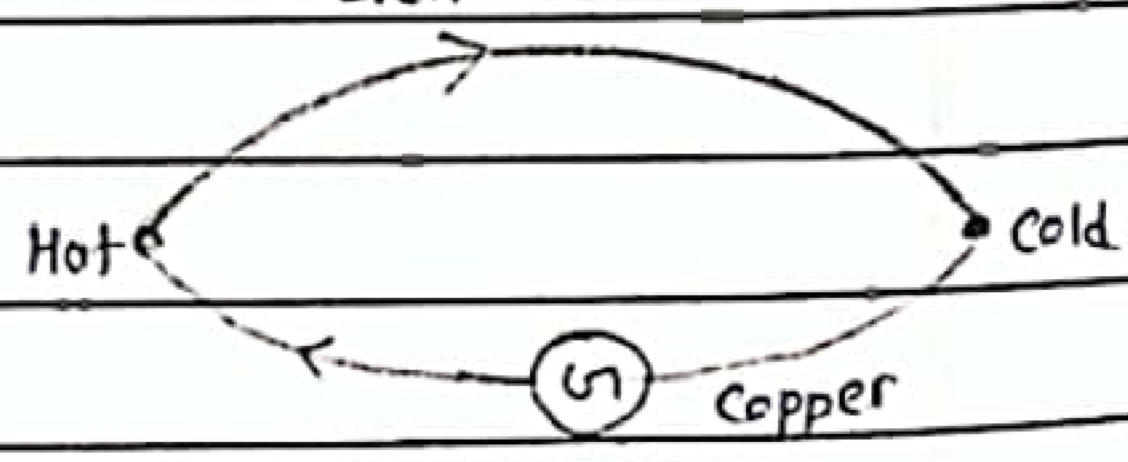

Fig: Iron-copper thermocouple

Thermoelectric series

An arrangement of metals in series in which any two metals can be used to form a thermocouple is called thermoelectric series.

The thermoelectric series is:
Antimony, Iron, Zinc, Silver, Lead, Copper, Platinum, Cobal, Bismuth.

Variation of Thermo emf with Temperature.

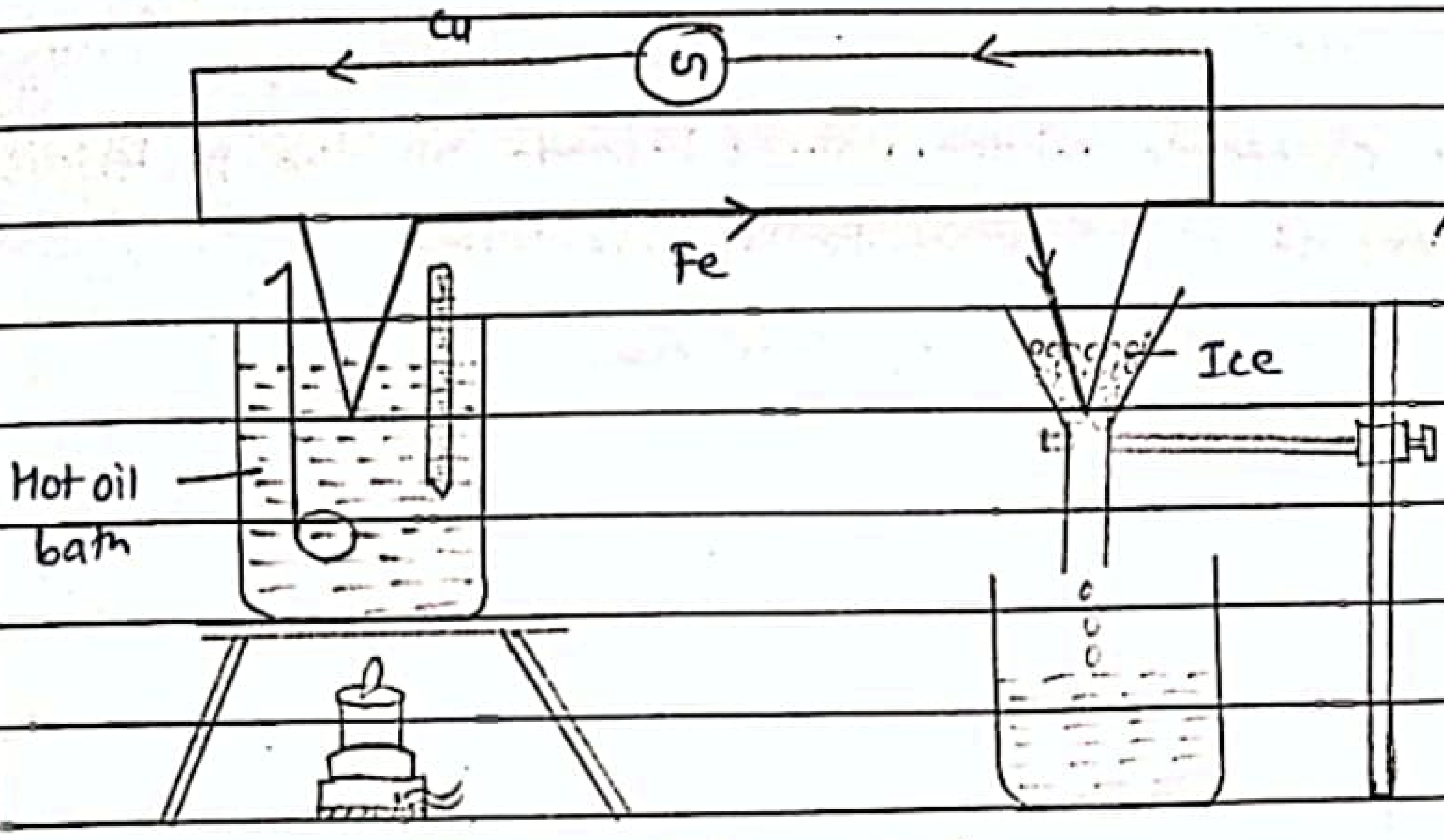

Fig: Cu-Fe thermocouple

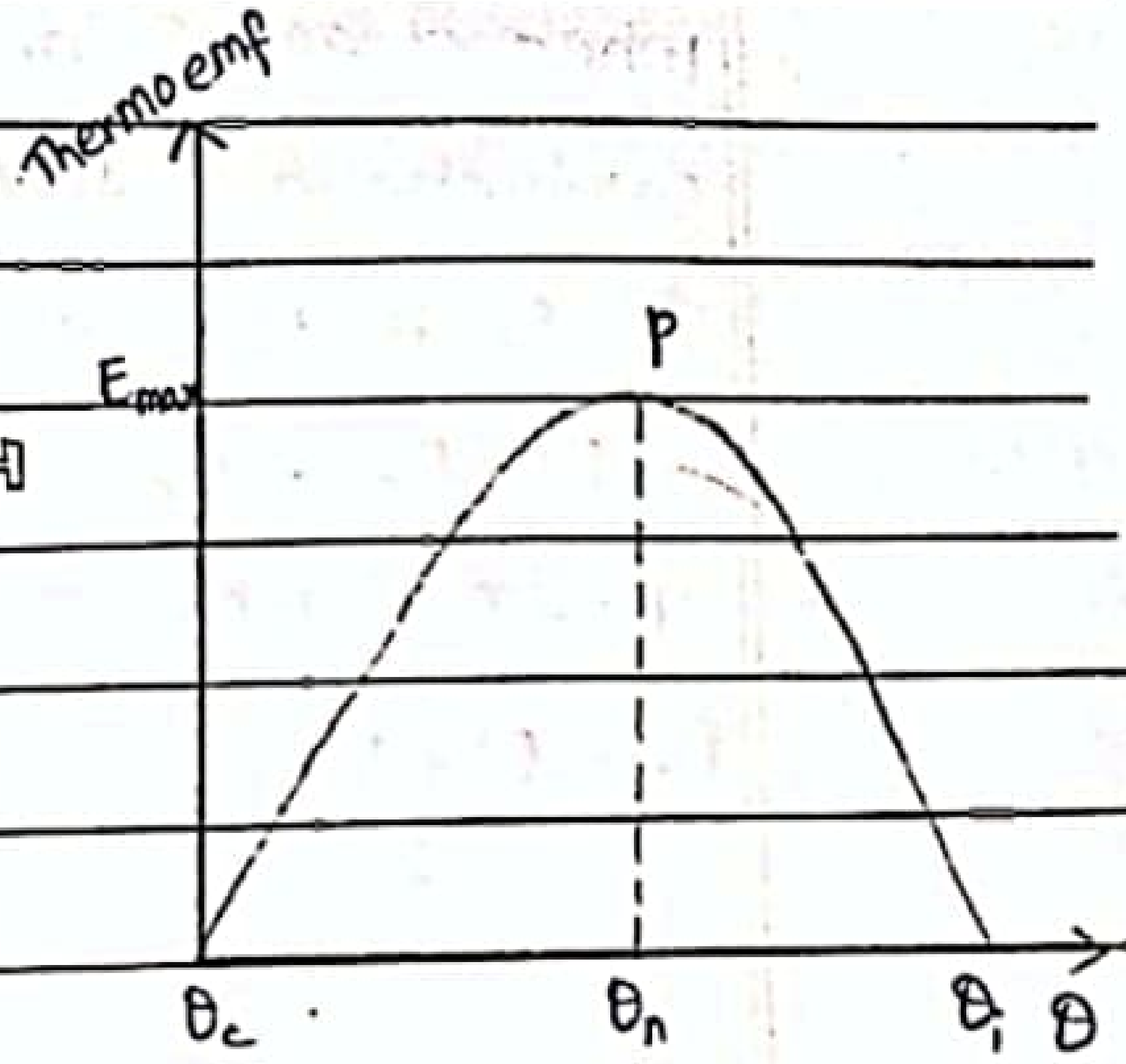

Fig: Variation of thermoemf with temperature

One junction is immersed in an oil bath and other is kept in melting ice whose temperature is kept constant. When the temperature of both junctions are same (0°C), the galvanometer shows no deflection and so, no emf is produced. The temperature of oil bath is increased gradually by heating it.

When the temperature of hot junction is increased, and the cold junction is kept at 0°C, emf increases till it becomes maximum at θ_n. The temperature of the hot junction at which the thermo emf becomes maximum is called neutral temperature (θ_n).

As the temperature of hot junction is increased beyond θ_n, thermo emf also decreases and ultimately becomes zero at temperature θ_n. The temperature of hot junction at which thermo emf is zero and changes its polarity is called temperature of inversion, θ_i.

If the temperature is increased beyond θ_i, the direction of thermoemf is reversed.

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The variation of thermo emf with temperature θ is given by:

$$E = \alpha\theta + \frac{1}{2}\beta\theta^2$$

where α and β are constants whose values depend on the materials of conductor and temperature difference of two junctions.

If θ_c is the temperature of cold junction, then

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

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

$\therefore$ $$\theta_n = \frac{\theta_i + \theta_c}{2}$$

Relation Among Thermoelectric constants α, β, θ_n and θ_i

Consider a thermocouple whose cold junction is kept at 0°c and θ be the temperature of hot junction, then the thermo emf is $E = \alpha\theta + \frac{1}{2}\beta\theta^2$. Differentiating this w.r.t. θ, we get.

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

At $\theta = \theta_n$, E is maximum. So, $\frac{dE}{d\theta} = 0$. The slope of E-θ graph $\left(\frac{dE}{d\theta}\right)$ at P is zero. So,

$$0 = \alpha + \beta\theta_n$$

or $$\theta_n = \frac{-\alpha}{\beta}$$

When $\theta = \theta_i$, E=0. So,

$$0 = \alpha\theta_i + \frac{1}{2}\beta\theta_i^2$$

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

As $\theta_i \neq 0$, $\alpha + \frac{1}{2}\beta\theta_i = 0$

or $\theta_i = -\frac{2\alpha}{\beta}$

Thermoelectric Power

The rate of change of thermo emf with temperature is called thermoelectric power. $P = \frac{dE}{d\theta}$

2 Peltier Effect

When an electric current is passed through a thermocouple, heat is either absorbed or released at the junctions, depending on the direction of current flow. This effect is called peltier effect. This is a reversible effect i.e. when direction of current is reversed, the heat evolved or absorbed is interchanged at the junctions.

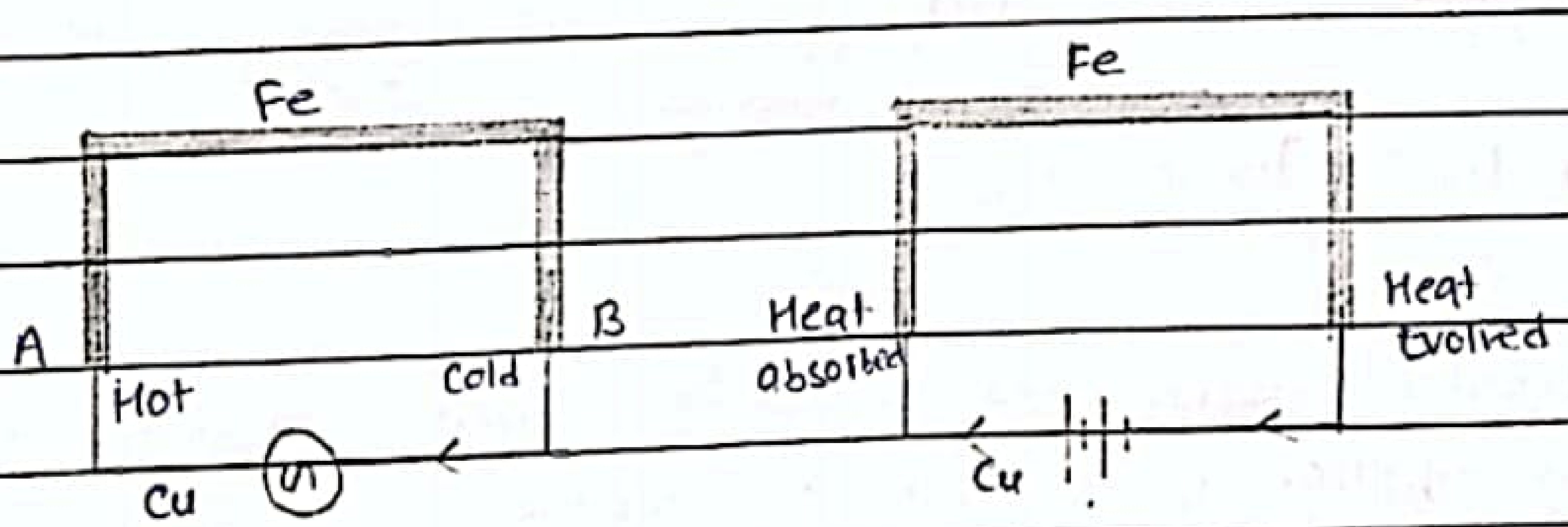

Fig: Peltier effect

If the direction of seebeck emf is from Cu to Fe at the hot junction, then an external emf applied in the same direction will produce cooling at this junction and heating at the other junction

Peltier Coefficient

Peltier coefficient at any temperature for the junction of two metals is the product of absolute temperature and thermoelectric power at that temperature.

$$\pi = TP = T\frac{dE}{d\theta}$$

Thomson Effect

The phenomenon of evolution or absorption of heat (other than Joule's law) along the length of a conductor on passing current through it when its two ends are kept at different temperature is known as Thomson effect.

- **Positive Thomson effect**

The evolution of heat in the part of conductor along which current flows in the direction of temperature fall is called positive Thomson effect. It is seen in Cu, Cd, Zn, Ag and Sb.

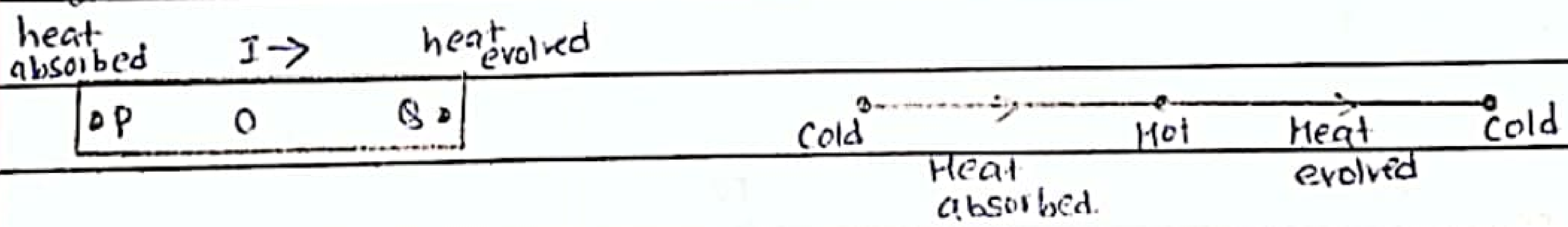

Fig: Positive Thomson effect.

- **Negative Thomson effect:**

When a current is passed in iron rod in the direction from P to Q, the point P becomes hotter than point Q i.e. heat energy is transferred in a direction opposite to that of current. This is negative Thomson effect. It is seen in Fe, Pt, Bi, Co, Ni and Hg.

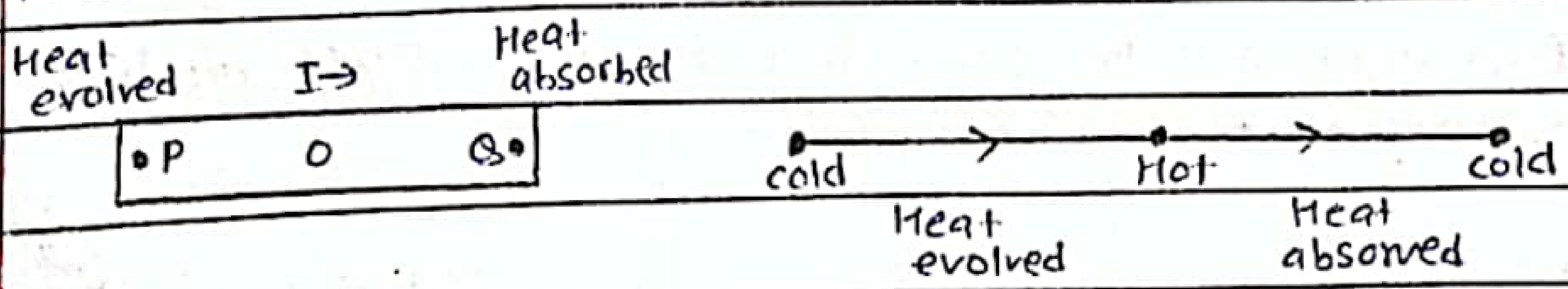

Fig: Negative Thomson effect.

Thermopile

It is a device used for the detection and measurement of heat radiation. It is based on Seebeck effect. It is constructed on the principle that if a no. of thermocouples are connected in series, then the thermo emf gets multiplied.

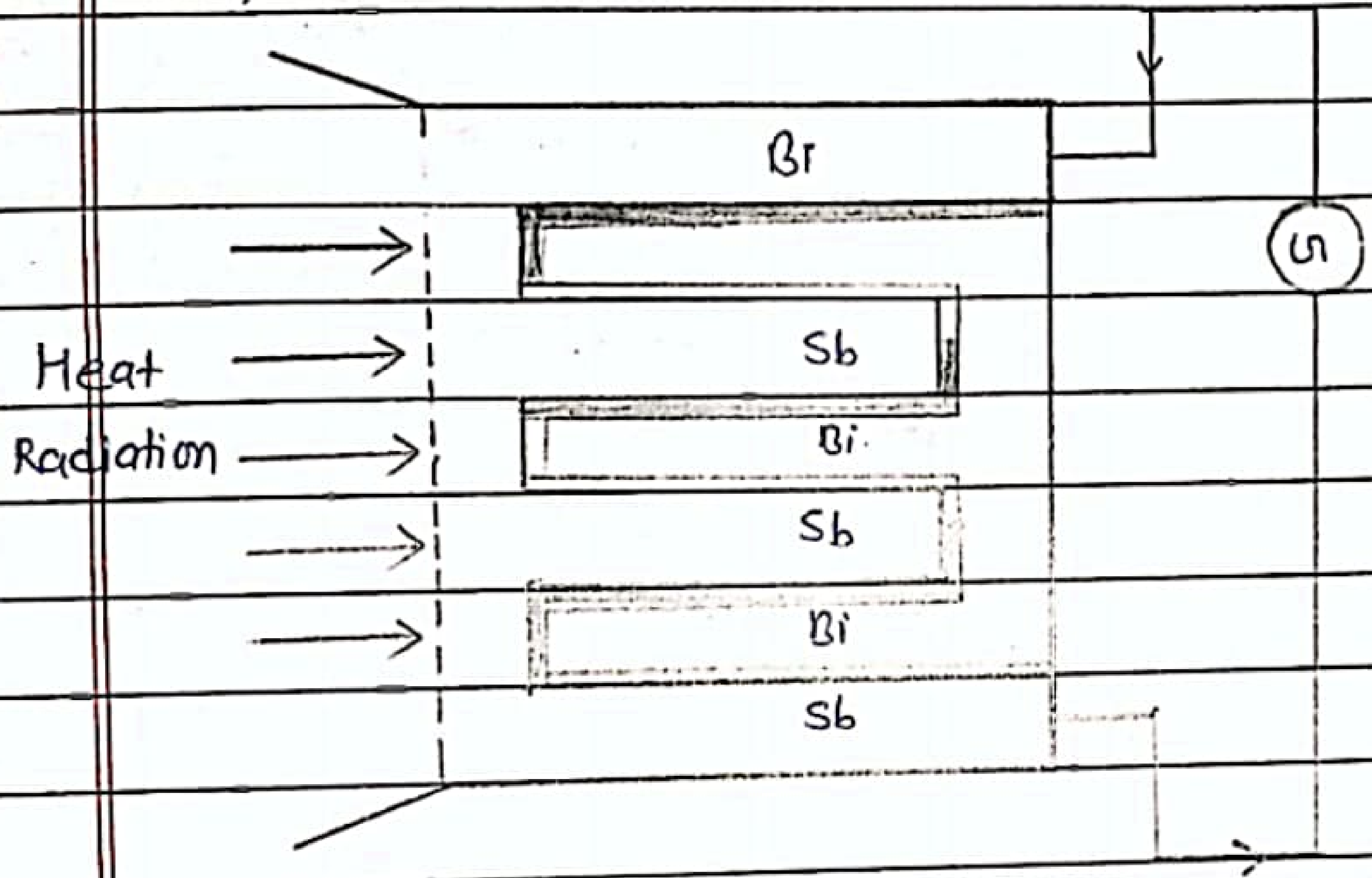

Fig: Bi-Sb Thermopile