Unit 15 · Thermoelectric Effect

HARDER PRACTICE QUESTIONS

Full marks 32

Write your answers on separate paper. Show your working. In every question the cold junction is at 0 °C unless the question says otherwise.

1 Spot the error [3]

Find the mistake in the working and correct it.

Rohan was told that a thermocouple's e.m.f. is $E = a\theta + b\theta^2$, with a = 20 μV/°C and b = −0.04 μV/°C², and asked for its neutral temperature. He wrote:

"$\theta_n = -\frac{\alpha}{\beta} = -\frac{a}{b} = \frac{20}{0.04} = 500$ °C."

2 Read the data [4]

Prapti measured the e.m.f. of a thermocouple with its hot junction at several temperatures.

θ (°C)	50	100	150	200	250	300
E (μV)	700	1200	1500	1600	1500	1200

i. What is the neutral temperature? How do the readings show it?

ii. Predict the temperature of inversion.

iii. Using the readings at 50 °C and 100 °C, find α and β in $E = \alpha\theta + \frac{1}{2}\beta\theta^2$.

iv. Check your values against the reading at 200 °C.

3 Predict, then explain [3]

Write your prediction first, then explain it.

The thermocouple of question 2 ($\alpha = 16$ μV/°C, $\beta = -0.08$ μV/°C²) has its cold junction moved from 0 °C to 40 °C. Predict what happens to its neutral temperature, its temperature of inversion and its largest e.m.f. Then work them out.

4 Show that [3]

For a thermocouple with $E = \alpha\theta + \frac{1}{2}\beta\theta^2$, show that the greatest e.m.f. it can give is $E_{\max} = -\frac{\alpha^2}{2\beta}$.

Check it with the values of question 2.

5 Estimate it [4]

A thermoelectric module on a wood stove in a village with no electricity grid has 50 W of heat flowing through it. Thermoelectric generators turn a few percent to about 8 % of the heat into electricity.

i. Taking 5 %, what electrical power does it give?

ii. Suppose a phone battery stores 10 Wh. Roughly how long would the module take to charge it, ignoring other losses?

iii. Give two reasons why such a generator is used even though it wastes most of the heat.

6 Which explanation fits? [2]

Two explanations of the Seebeck e.m.f. are given: A, it is made at the junctions by contact potentials; B, it is made along the wires, wherever there is a temperature gradient. A thermocouple gives the same e.m.f. whether its junctions are soldered, welded or just twisted. Which explanation does this support? Why?

7 Correct the misconceptions [3]

The paragraph has three mistakes. Write each mistake and correct it.

> Monika wrote: "The Peltier effect is just Joule heating at a junction, so reversing the current changes nothing. The Thomson effect needs two different metals. A thermopile works on the Peltier effect."

8 What if? [3]

A current is passed through a small Peltier cooler, and one side becomes cold. What happens to that side i. if the current is reversed, ii. if the current is doubled? Think about both the Peltier heat and the Joule heat.

9 Work backwards [3]

A thermocouple with its cold junction at 30 °C has its temperature of inversion at 410 °C. Its α is 11 μV/°C. Find its neutral temperature and its β (in $E = \alpha\theta + \frac{1}{2}\beta\theta^2$).

10 Design it [2]

Sagar has wires of copper, platinum, iron and nickel. Which two should he join to get the largest thermo e.m.f.? Through the cold junction, which way will the current flow?

11 Make your own [2]

Write a problem about a thermocouple with $E = a\theta + b\theta^2$ whose answer is "the neutral temperature is 300 °C". Solve it to show it works.