Unit 15 · Thermoelectric Effect

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 32

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Spot the error

ANSWER U · 3

He used the formula for the form $E = \alpha\theta + \frac{1}{2}\beta\theta^2$, where b = ½$\beta$, not β. For $E = a\theta + b\theta^2$,

$dE/d\theta = a + 2b\theta = 0$, so $\theta_n = -\frac{a}{2b} = \frac{20}{0.08} =$ **250 °C**. His 500 °C is the temperature of inversion, −a/b.

MARKING SCHEME

- ✓ The error: b in this form is ½β, so θn ≠ −a/b.
- ✓ dE/dθ = a + 2bθ = 0.
- ✓ θn = 250 °C (500 °C is the temperature of inversion).

2 Read the data

ANSWER A · 4

(The readings are made up, from $\alpha = 16$ μV/°C and $\beta = -0.08$ μV/°C^2.)

i. **200 °C**: E is greatest there, and the readings are symmetric about it (1500 μV at 150 °C and at 250 °C; 1200 μV at 100 °C and 300 °C).

ii. θi = 2θn = **400 °C**.

iii. $50\alpha + 1250\beta = 700$ and $100\alpha + 5000\beta = 1200$. Doubling the first and subtracting: $2500\beta = -200$, so β **= −0.08 μV/°C^2** and α **= 16 μV/°C**.

iv. E = 16 × 200 − 0.04 × 200^2 = 3200 − 1600 = 1600 μV, as measured (and $-\alpha/\beta = 200$ °C).

MARKING SCHEME

- ✓ θn = 200 °C, from the symmetry of the readings.
- ✓ θi = 400 °C.
- ✓ $\alpha = 16$ μV/°C and $\beta = -0.08$ μV/°C^2.
- ✓ The check gives 1600 μV at 200 °C.

3 Predict, then explain

ANSWER HA · 3

The neutral temperature **stays at 200 °C** ($-\alpha/\beta$ has no θc in it). The temperature of inversion **falls**, to 2 × 200 − 40 = **360 °C**. The largest e.m.f. **falls** too: it is now E(200) − E(40) = 1600 − (640 − 64) = **1024 μV**, since the cold junction gives back what the curve had reached by 40 °C.

MARKING SCHEME

- ✓ θn stays 200 °C.
- ✓ θi falls to 360 °C.
- ✓ The largest e.m.f. falls to 1024 μV.

4 Show that

MARKING SCHEME A · 3

- ✓ θn = $-\alpha/\beta$ put into E.
- ✓ Simplified to $-\alpha^2/(2\beta)$.
- ✓ 1600 μV, as in the table.

5 Estimate it

ANSWER

i. 0.05 × 50 W = **2.5 W**.

ii. 10 Wh ÷ 2.5 W = **about 4 hours**.

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iii. It has no moving parts, so it is silent, reliable and lasts for decades; and the heat comes from a fire that is burning anyway, so nothing extra is spent where there is no grid. **A · 4**

MARKING SCHEME

- ✓ 2.5 W.
- ✓ About 4 hours.
- ✓ No moving parts: silent and reliable (lasts long).
- ✓ The heat is there anyway (useful where there is no grid).

6 Which explanation fits?

MARKING SCHEME **U · 2**

- ✓ B, made along the wires.
- ✓ The kind of joint makes no difference, so the junction only marks where the metals change.

7 Correct the misconceptions

ANSWER **U · 3**

1. The Peltier effect is **not** Joule heating: it is reversible, so reversing the current makes the heated junction cool and the cooled one warm.
2. The Thomson effect happens in a **single** conductor whose ends are at different temperatures.
3. A thermopile works on the **Seebeck** effect: radiation warms one set of junctions and the difference of temperature makes an e.m.f.

MARKING SCHEME

- ✓ The Peltier effect is reversible, unlike Joule heating.
- ✓ The Thomson effect is in a single conductor.
- ✓ A thermopile works on the Seebeck effect.

8 What if?

ANSWER **HA · 3**

i. The cold side becomes the hot side, and the hot side the cold: the Peltier effect is reversible.

ii. The heat taken in at the cold junction by the Peltier effect doubles (it is proportional to I), but the Joule heat in the device becomes four times as much (proportional to I^2). So doubling the current cools more only while the Joule heat is small; at large currents the Joule heat wins and the cold side cools less, or even warms.

MARKING SCHEME

- ✓ Reversed: the cold and hot sides swap.
- ✓ Peltier heat $\propto$ I (doubles), Joule heat $\propto I^2$ (four times).
- ✓ So more current does not always mean more cooling: Joule heating takes over.

9 Work backwards

ANSWER **A · 3**

$\theta_n = \frac{\theta_c + \theta_i}{2} = \frac{30 + 410}{2} = \mathbf{220\ ^\circ C}$. Then $\beta = -\frac{\alpha}{\theta_n} = -\frac{11}{220} = \mathbf{-0.05\ \mu V/^\circ C^2}$.

MARKING SCHEME

- ✓ $\theta n = (\theta c + \theta i)/2$.
- ✓ $\theta n = 220\ ^\circ C$.
- ✓ $\beta = -\alpha/\theta n = -0.05\ \mu V/^\circ C^2$.

10 Design it

MARKING SCHEME **A · 2**

- ✓ Iron and nickel (farthest apart in the series).
- ✓ From iron to nickel through the cold junction.

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11 Make your own

HA · 2

ANSWER

For example: "a = 18 μV/°C and b = −0.03 μV/°C^2. Find the neutral temperature." $\theta n = -a/(2b) = 18 \div 0.06 = 300$ °C. Any a and b with a = −600b (b negative) is right.

MARKING SCHEME

- ✓ A sensible problem with b negative.
- ✓ Solved correctly to 300 °C with $\theta n = -a/(2b)$.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	8	16	8	**32**

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