문제 E1 — 풀이

구리 막대에서의 열전도 (10점)

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

파트 A: 짧은 구리 막대 (3.9점)

**A.1 (0.2 pt)**

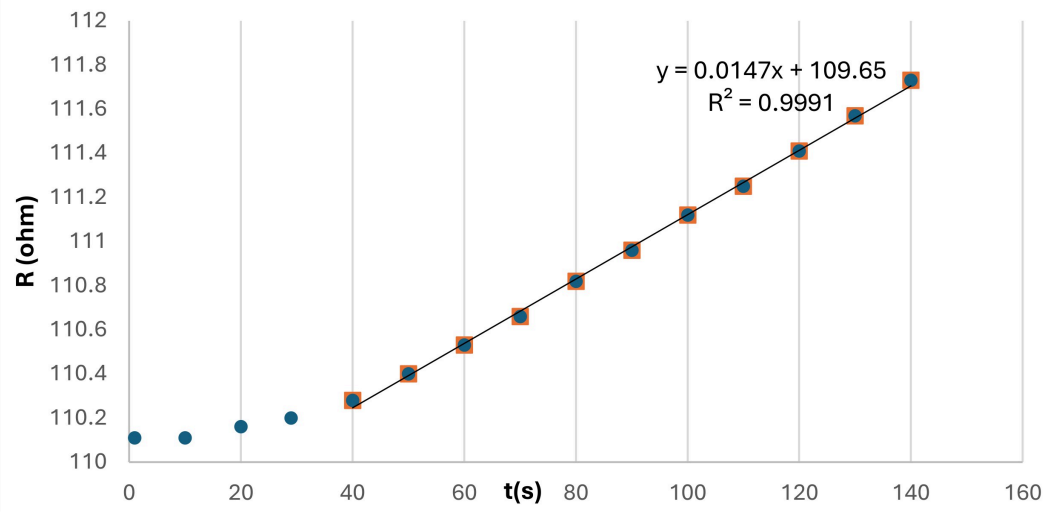
$$R_{en} = 110.11 \pm 0.01\ \Omega \qquad \theta_{en} = \frac{R - R_0}{R_0 \alpha}$$

$$\theta_{en} = 25.87 \pm 0.03\ ^\circ\mathrm{C}$$

**A.2 (0.5 pt)**

| n | $R\,(\Omega)$ | $t\,(\mathrm{s})$ |
|---|---|---|
| 1 | 110.11 | 1 |
| 2 | 110.11 | 10 |
| 3 | 110.15 | 20 |
| 4 | 110.18 | 30 |
| 5 | 110.26 | 40 |
| 6 | 110.4 | 50 |
| 7 | 110.53 | 60 |
| 8 | 110.66 | 70 |
| 9 | 110.82 | 80 |
| 10 | 110.96 | 90 |
| 11 | 111.12 | 100 |
| 12 | 111.25 | 110 |
| 13 | 111.41 | 120 |
| 14 | 111.57 | 130 |
| 15 | 111.73 | 140 |

**A.3 (0.8 pt)**



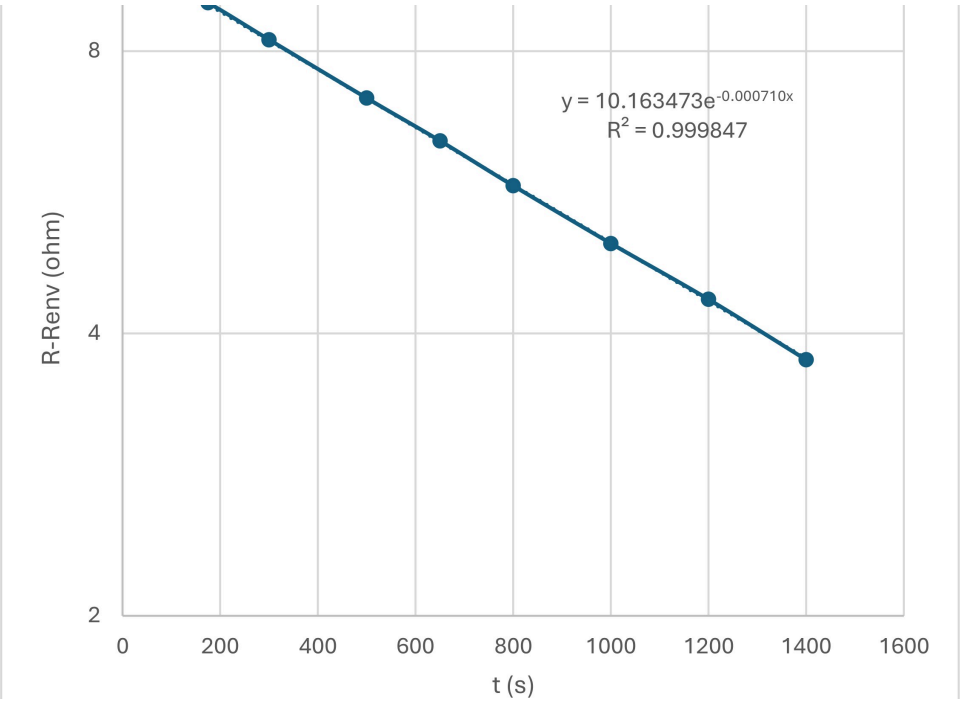

| | | |
|---|---|---|
| $\Delta R/\Delta t$ | $0.0147\ \Omega/\mathrm{s}$ | $\dfrac{\Delta\theta}{\Delta t}=\dfrac{1}{R_0\alpha}\dfrac{\Delta R}{\Delta t}$ |
| $\Delta\theta/\Delta t$ | $0.03761\ ^\circ\mathrm{C}/\mathrm{s}$ | |
| $C_s$ | $52\pm 2\ \mathrm{J}/^\circ\mathrm{C}$ | |

$$C_s=\frac{P_1}{\frac{\Delta\theta}{\Delta t}},\quad \Delta C_s\approx C_s\frac{\Delta P_1}{P_1}$$

**A.4 (0.5 pt)**

| n | $R\,(\Omega)$ | $t\,(\mathrm{s})$ | $(R-R_{en})\,(\Omega)$ |
|---|---|---|---|
| 1 | 119.98 | 40 | 9.82 |
| 2 | 119.17 | 175 | 9.01 |
| 3 | 118.39 | 300 | 8.23 |
| 4 | 117.29 | 500 | 7.13 |
| 5 | 116.58 | 650 | 6.42 |
| 6 | 115.91 | 800 | 5.75 |
| 7 | 115.15 | 1000 | 4.99 |
| 8 | 114.51 | 1200 | 4.35 |
| 9 | 113.91 | 1400 | 3.75 |
| 10 | 113.40 | 1600 | 3.24 |

**A.5 (0.7 pt)**

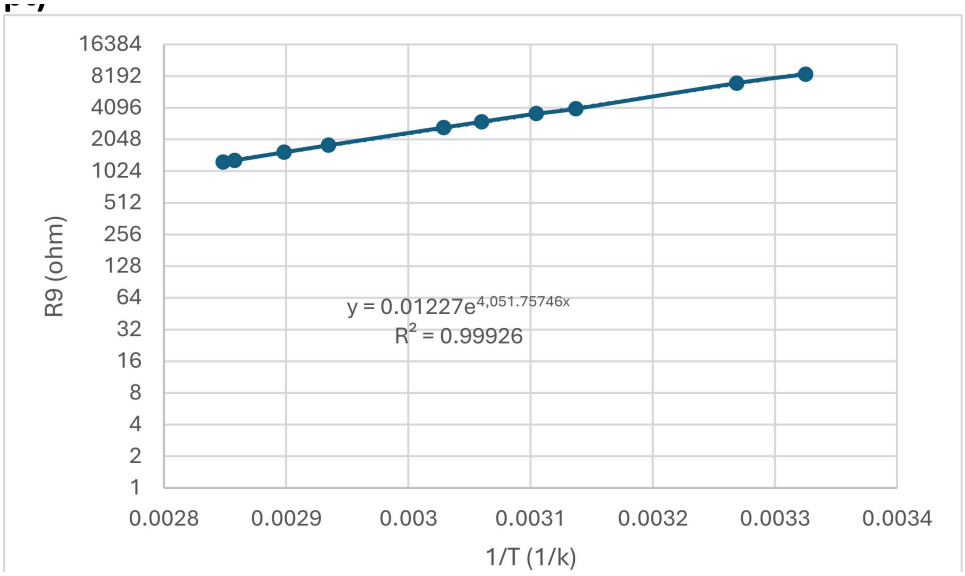



$$\gamma = (710 \pm 3) \times 10^{-6}\ \mathrm{s}^{-1}$$

**A.6 (0.5 pt)**

| n | $R_9\,(\Omega)$ | $R\,(\Omega)$ | $T\,(\mathrm{K})$ | $\frac{1}{T}\,(1/\mathrm{K})$ |
|---|---|---|---|---|
| 1 | 8528 | 110.78 | 300.733 | 0.003325 |
| 2 | 7020 | 112.81 | 305.9272 | 0.003269 |
| 3 | 4005 | 117.83 | 318.772 | 0.003137 |
| 4 | 3601 | 119.13 | 322.0984 | 0.003105 |
| 5 | 3014 | 120.96 | 326.7808 | 0.00306 |
| 6 | 2658 | 122.27 | 330.1328 | 0.003029 |
| 7 | 1803 | 126.42 | 340.7515 | 0.002935 |
| 8 | 1547 | 128.09 | 345.0245 | 0.002898 |
| 9 | 1296 | 130.00 | 349.9117 | 0.002858 |
| 10 | 1246 | 130.45 | 351.0631 | 0.002848 |

**A.7 (0.7 pt)**



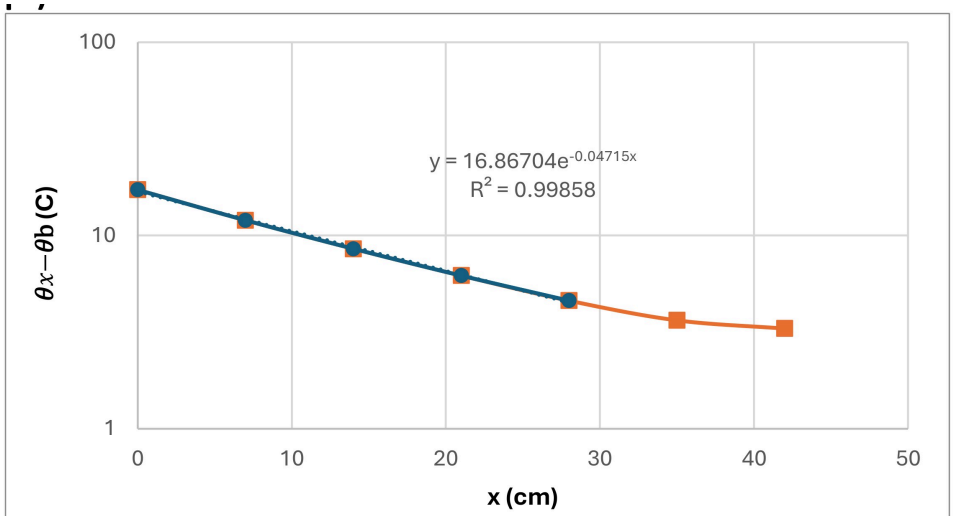

$E_g = 0.698 \pm 0.007\ \text{eV}$

파트 B: 긴 구리 막대 (4.1점)

**B.1 및 B.5**

$\theta_b = 24.41\ ^\circ\text{C}$

**B.2 (0.4 pt)**




**B.3 (0.6 pt)** **B.4 (0.4 pt)**

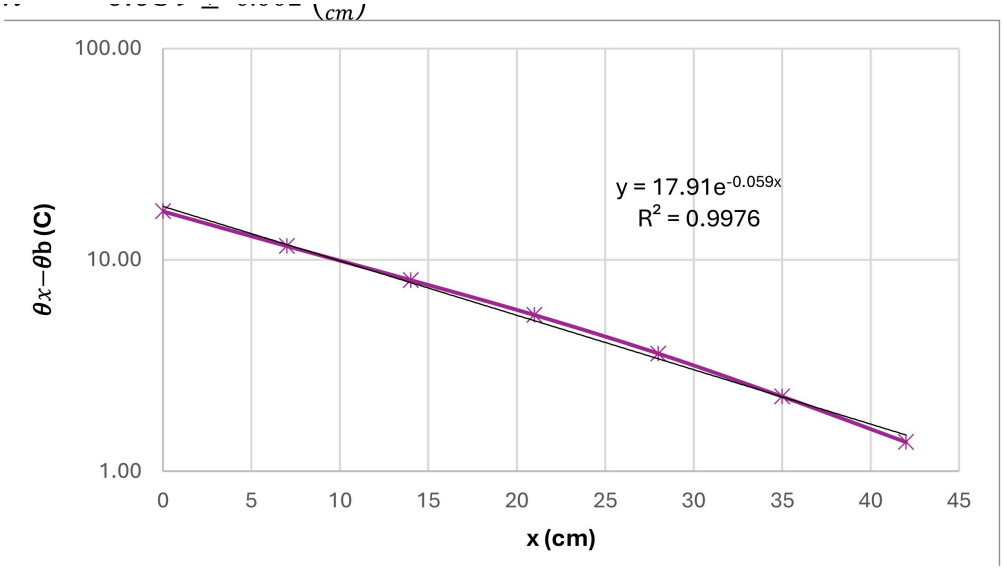
$A^{(0)} = 16.87\ ^\circ\text{C} \qquad B = Ae^{-2\lambda d}$

$\lambda^{(0)} = 0.047 \pm 0.005\ (1/\text{cm}) \qquad B^{(1)} = 0.266\ ^\circ\text{C}$

**B.6 (1.0 pt)**

$A^{(1)} = 17.91\ ^\circ\mathrm{C}$

$\lambda^{(1)} = 0.059 \pm 0.002\ (1/\mathrm{cm})$




**B.7 (0.9 pt)**

$$P_2 = \int_{-0.5\ \mathrm{cm}}^{42.5\ \mathrm{cm}} 2\pi r h(\theta_x - \theta_b)\,dx \quad \text{또는} \quad \int_0^d 2\pi r h(\theta_x - \theta_b)\,dx = \frac{2\pi r h A}{\lambda}\left(1 - e^{-2\lambda d}\right)$$

$$h = \frac{P_2 \lambda}{2\pi r A\left(1 - e^{-2\lambda d}\right)}, \quad k = \frac{2h}{\lambda^2 r}, \quad P_2 = 4.5\ \mathrm{W}$$

$\lambda = 0.053 \pm 0.008\ (1/\mathrm{cm}), \quad h = 0.0037 \pm 0.0003\ \mathrm{W/(K\,cm^2)}, \quad k = 3.9 \pm 0.3\ \mathrm{W/(K\,cm)}$

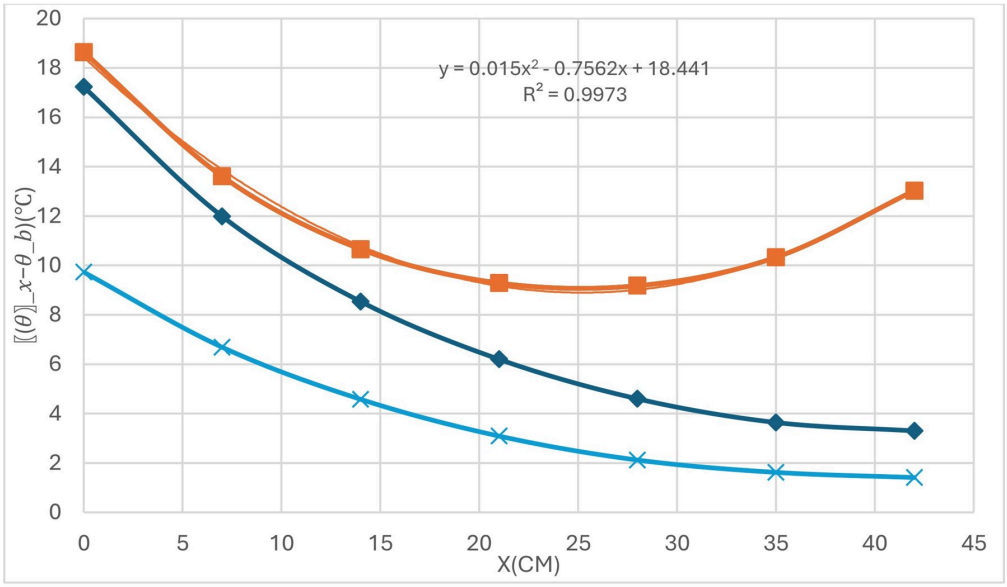
파트 C: 미지의 출력 측정 (2.0점)

**C.1 (0.4 pt)**

$\theta_b = 27.38\ ^\circ\mathrm{C}$

| n | $x\ (\mathrm{cm})$ | $\theta_x\ (^\circ\mathrm{C})$ | $(\theta_x - \theta_b)\ (^\circ\mathrm{C})$ | B-1 | C-B | 역순 |
|---|---|---|---|---|---|---|
| 1 | 0 | 46.02 | 18.64 | 17.23 | 1.41 | 9.73 |
| 2 | 7 | 40.99 | 13.61 | 11.99 | 1.62 | 6.69 |
| 3 | 14 | 38.04 | 10.66 | 8.54 | 2.12 | 4.58 |
| 4 | 21 | 36.67 | 9.29 | 6.2 | 3.09 | 3.09 |
| 5 | 28 | 36.56 | 9.18 | 4.6 | 4.58 | 2.12 |
| 6 | 35 | 37.71 | 10.33 | 3.64 | 6.69 | 1.62 |
| 7 | 42 | 40.41 | 13.03 | 3.3 | 9.73 | 1.41 |

**C.2 (0.6 pt)**




(파란 점들은 그릴 필요가 없다)

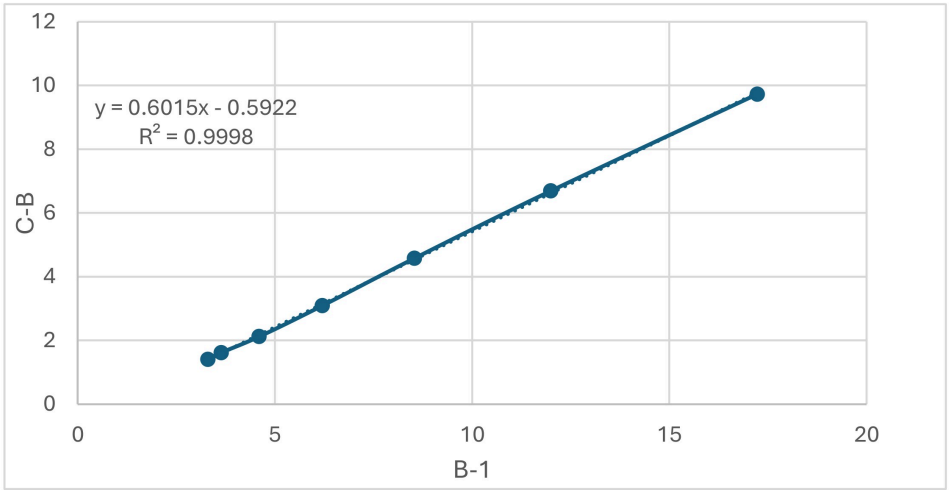
**C.3 (1.0 pt)**

1) $$\frac{P_3}{P_2} = \frac{\left.\frac{d\theta}{dx}\right|_{x=42\ \mathrm{cm}}}{\left.\frac{d\theta}{dx}\right|_{x=0\ \mathrm{cm}}} = \frac{\left.\frac{\Delta\theta}{\Delta x}\right|_{x=42\ \mathrm{cm}}}{\left.\frac{\Delta\theta}{\Delta x}\right|_{x=0\ \mathrm{cm}}} = \frac{\theta_7 - \theta_6}{\theta_0 - \theta_1}$$

2) $$\frac{P_3}{P_2} = \frac{\left.\frac{d\theta}{dx}\right|_{x=42\ \mathrm{cm}}}{\left.\frac{d\theta}{dx}\right|_{x=0\ \mathrm{cm}}} = \frac{\sinh(\lambda(42 - x_0))}{\sinh(\lambda x_0)}$$

3) 적분법 또는 여러 구간의 합으로 계산

4) 기울기 ((C−B) 대 (B−1))




$$P_3 = 0.60\,P_2 \pm 0.01\,P_2$$