

Problem E1-Marking scheme Heat Conduction in a Copper Rod (10 points)

Part A: The short copper rod (3.9 points)

A.1 (0.2 pt)	0.05 points if $112 > R_{env} > 108 \Omega$ $\Delta R_{env} = \pm 0.01 \Omega$ (0.05 pt)	0.1 pt
	This value should be calculated from this equation $\theta_{env} = \frac{R-R_0}{R_0 \alpha}$. Calculation of θ_{env} using the obtained results (0.05 pt) Calculation of the uncertainty $\Delta \theta_{env} = \pm 0.03$ (0.05 pt)	0.1 pt
A.2 (0.5 pt)	Missing measurement points less than 15 time (-0.04 each) For each interval out of range 8-12 seconds (-0.02 each) Wrong measurement of resistance (-0.04 each)	0.5 pt
A.3 (0.8 pt)	Graph (max 0.4) Data points are properly plotted. (0.3) Too small (-0.1) Missing of the quantities or units (-0.1) Line to determine the slope (0.1)	0.4 pt
	Reading of $\frac{\Delta R}{\Delta t}$ from the graph or calculator. $\frac{\Delta R}{\Delta t}$ is in range $0.0138 \leq \frac{\Delta R}{\Delta t} \leq 0.0165 \frac{\Omega}{s}$ (0.1) Missing or incorrect units (-0.05)	0.1 pt
	Calculation of $\frac{\Delta \theta}{\Delta t} = \frac{1}{R_0 \alpha} \frac{\Delta R}{\Delta t}$ using the obtained result.	0.1 pt
	$47 \leq C_s \leq 52 \text{ J/}^\circ\text{C}$ (0.1 pt) , $44 \leq C_s \leq 55 \text{ J/}^\circ\text{C}$ (0.05 pt) . Missing or incorrect units (-0.05)	0.1 pt
	Correct ΔC_s formula (0.05 pt) Calculation of the uncertainty $\Delta C_s = \pm 1 \text{ or } 2 \text{ J/}^\circ\text{C}$ (0.05 pt)	0.1 pt
A.4 (0.5 pt)	Missing measurement points less than 10 time (-0.05 each)	0.5 pt
A.5 (0.7 pt)	Graph (max 0.4) Data points are properly plotted (0.3). Too small (-0.1) Missing of the axes or quantities or units (-0.1) Missing points (-0.04 each) Line to determine the slope (0.1)	0.4 pt
	$6.5 \times 10^{-4} \leq \gamma \leq 7.5 \times 10^{-4} \text{ 1/s}$ (0.2 pt), $6 \times 10^{-4} \leq \gamma \leq 8 \times 10^{-4} \text{ 1/s}$ (0.1 pt) Missing or incorrect units (-0.05)	0.2 pt
	Calculation of the uncertainty $\Delta \gamma$ (0.05 pt), Correct $\Delta \gamma$ formula (0.05 pt)	0.1 pt
A.6 (0.5 pt)	Missing measurement points less than 7 time (-0.05 each) For not covering a resistance range of 5Ω , each 0.5Ω (-0.02) Inconvenient distribution of data points (up to -0.1)	0.5 pt
A.7 (0.7 pt)	Graph (max 0.4) Data points are properly plotted (0.3). Too small (-0.1) Missing of the axes or quantities or units (-0.1) Missing points (-0.04 each) Line to determine the slope (0.1)	0.4 pt
	$0.68 \leq E_g \leq 0.72 \text{ eV}$ (0.2), $0.66 \leq E_g \leq 0.74 \text{ eV}$ (0.1) Missing or incorrect units (-0.05)	0.2 pt
	Calculation of the uncertainty ΔE_g	0.1 pt
Part B: The long copper rod (4.1 points)		
B.1 (0.4 pt)	Missing measurement points less than 7 time (-0.05 each) $22 > \theta_1 - \theta_b > 15^\circ\text{C}$ and $\theta_7 - \theta_b > 3^\circ\text{C}$ (0.1)	0.4 pt

B.2 (0.4 pt)	Graph (max 0.4) Data points are properly plotted (0.3). Too small (-0.1) Missing of the axes or quantities or units (-0.1) Missing points (-0.05 each) Line to determine the slope (0.1)	0.4 pt
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B.3 (0.6 pt)	Calculation of $A^{(0)}$ using the obtained results. Missing or incorrect units(-0.05)	0.2 pt
	$0.046 \leq \lambda^{(0)} \leq 0.051 \left(\frac{1}{cm}\right)$ (0.3), $0.044 \leq \lambda^{(0)} \leq 0.053 \left(\frac{1}{cm}\right)$ (0.2) Missing or incorrect units (-0.05)	0.3 pt
	Calculation of the uncertainty $\Delta\lambda^{(0)}$	0.1 pt

B.4 (0.4 pt)	$B = Ae^{-2\lambda d}$ Correct equation	0.2 pt
	Calculation of B(1) using the obtained results	0.2 pt

B.5(0.4)	Incorrect calculation (-0.05 each)	0.4 pt
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B.6 (1.0 pt)	Graph (max 0.4) Data points are properly plotted (0.3). Too small (-0.1) Missing of the axes or quantities or units (-0.1) Missing points (-0.05 each) Line to determine the slope (0.1)	0.4 pt
	Calculation of $A^{(1)}$ using the obtained results. Missing or incorrect units (-0.05)	0.2 pt
	$0.054 \leq \lambda^{(1)} \leq 0.063 \left(\frac{1}{cm}\right)$ (0.3), $0.051 \leq \lambda^{(1)} \leq 0.068 \left(\frac{1}{cm}\right)$ (0.2) Missing or incorrect units (-0.05)	0.3 pt
	Calculation of the uncertainty $\Delta\lambda^{(1)}$	0.1 pt

B.7 (0.9 pt)	Calculation of the uncertainty λ	0.2 pt
	Calculation of the uncertainty $\Delta\lambda$	0.1 pt
	Correct formula for h (0.1), Calculation of h using the obtained results (0.1)	0.2 pt
	Calculation of the uncertainty Δh	0.1 pt
	Correct formula for k (0.1), Calculation of k using the obtained results (0.1)	0.2 pt
	Calculation of the uncertainty Δk	0.1 pt

Part C: Measuring the unknown power (2.0 points)

C.1 (0.4 pt)	Missing measurement points less than 7 time (-0.05 each)	0.3 pt
	$25 > \theta_1 - \theta_b > 15^\circ\text{C}$ and $\theta_7 - \theta_b > 10^\circ\text{C}$ (0.1)	0.1 pt

C.2 (0.6 pt)	Graph (max 0.4) Data points are properly plotted (0.3). Too small (-0.1) Missing of the axes or quantities or units (-0.1) Missing points (-0.05 each) Plot a curve trough the data (0.1)	0.4 pt
	Find x_0 using the Quad mod on the calculator or find x_0 from graph (0.1) $24.5 \leq x_0 \leq 25.5 \text{ cm}$ (0.1), $24 \leq x_0 \leq 26 \text{ cm}$ (0.05)	0.2 pt

C.3 (1.0 pt)	Calculation by subtracting the results of part C and B and calculating the slop of the line (0.6) Calculation by sinh and x_0 (0.4) Calculation by the integral (0.4) Calculate the slope of 2 points (0.2) Another method (?)	0.6 pt
	$0.59 \leq \frac{P_3}{P_2} \leq 0.61$ (0.3), $0.58 \leq \frac{P_3}{P_2} \leq 0.62$ (0.2), $0.57 \leq \frac{P_3}{P_2} \leq 0.63$ (0.1) Missing or incorrect units (-0.05) Calculation of the uncertainty P_3 (0.1)	0.4 pt