Wiedemann-Franz Law – Marking Scheme

Part A: Electric conductivity of metals (1.5 points)

A.1	Measuring magnet fall (1.0 pts)	
	The number of total measurements : if $N \le 15$	0.2 pts
	if $15 < N \le 21$	0.5 pts
	if $N > 21$	0.7 pts
	Average travel time within 10% of solution for 2 out of 3 rods	0.3 pts
A.2	Calculation of conductivity (0.5 pts)	
	Correct calculation of conductivity from A1	0.1 pts
	Final result for 2 out of 3 values: Within 10% of correct value	0.4 pts
	Within 20% of correct value	0.2 pts

Part B: Thermal conductivity of copper (3.0 points)

B.1	Writing room temperature with units	0.1 pts
B.2	Design a 4-probe circuit (0.5 pts)	
	Drawing ammeter in series with source and heater	0.2 pts
	Measuring voltage on heater and not power source	0.3 pts
B.3	Writing the equation for power and proper calculation	0.1 pts
B.4	Writing thermometers readings (0.5 pts)	
	Complete set (24 temperatures in table)	0.2 pts
	Units	0.1 pts
	2 digits after decimal point	0.1 pts
	Times within 1 minute of requirement (15,17.5,20 minutes)	0.1 pts
B.5	Thermal equilibrium graph (1.0 pts)	
	All 24 points are plotted	0.4 pts
	Correct axes, with units	0.2 pts

	Points span on 1/2 the area of graph paper	0.2 pts
	Slope is sketched for 17.5 min	0.2 pts
B.6	Obtaining κ_0 (0.5 points)	
	Correct expression for κ_0	0.1 pts
Op.1	Range of κ_0 $\left[W/(mK)\right]$: $404 \le \kappa_0 \le 446$	0.2 pts
	$382 \le \kappa_0 \le 468$	0.1 pts
	Range of $\Delta T/\Delta t\left[K/s\right]$: $1.25 \cdot 10^{-3} \le \Delta T/\Delta t \le 1.55 \cdot 10^{-3}$	0.2 pts
	$1.1 \cdot 10^{-3} \le \Delta T/\Delta t \le 1.7 \cdot 10^{-3}$	0.1 pts
Op.2	The value of the corrected κ (using the method in the solution) with κ_0 ,$\Delta T/\Delta t$ and c_p, P_{loss} from the official solution is in range:	
	$376 \le \kappa \le 416$	0.4
	$356 < \kappa < 376$ or $416 < \kappa < 436$	0.2
B.7	Correct answer - **Higher value**	0.3 pts

Part C: Heat loss and heat capacity of copper (4.0 points)

C.1	Cooling-Heating-Cooling cycle (1.0 pts)	
	Number of measurement points for each step: if $3 \le N < 5$	0.1 pts
	if $N \ge 5$	0.2 pts
	Heating step time in range $1[\min] \le t \le 3[\min]$	0.2 pts
	Cooling steps time $t > 200[s]$	0.2 pts
	If average between T4,T5 or average over all thermometers	0.2 pts
	Used only T4 or only T5	0.1 pts
	The reported temperature mid-heating is:	
	Less than 2.5 [C] away from average temperature in B.4	0.2 pts
	Between 2.5[C] and 4.0[C] from average temperature in B.4	0.1 pts

C.2	Cooling – Heating – Cooling graph (1.0 pts)	
	Correct axes, units on axes	0.2 pts
	Number of points on graph: $N \geq 15$	0.4 pts
	$12 \leq N < 15$	0.2 pts
	Points span on 1/2 the area of graph paper	0.2 pts
	Slope lines are plotted for cooling steps	0.2 pts
C.3	Obtaining c_p and P_{loss} (1.0 pts)	
	$P_{loss} = c_p \cdot m \cdot \left.\frac{\partial T_{av}}{\partial t}\right\|_{Cooling}$	0.2 pts
	$P_{in} = c_p \cdot m \cdot \left(\left.\frac{\partial T_{av}}{\partial t}\right\|_{Heating} - \left.\frac{\partial T_{av}}{\partial t}\right\|_{Cooling} \right)$ or $P_{in} \cdot \Delta t = c_p \cdot m \cdot \Delta T$	0.4 pts
	Range of c_p in $\left[J/(kg \cdot K) \right]$: $425 \leq c_p \leq 350$	0.2 pts
	$465 \leq c_p \leq 310$	0.1 pts
	Range of P_{loss} in $[W]$: $0.25 \leq P_{loss} \leq 0.38$	0.2 pts
	$0.19 \leq P_{loss} \leq 0.44$	0.1 pts
C.4	Correct κ (1.0 pts)	
	$c_p \cdot m \cdot \frac{\Delta T}{\Delta t}$	0.1 pts
	$c_p \cdot m \cdot \frac{\Delta T}{\Delta t}$ and P_{loss} are treated the same way	0.1 pts
	Form of equation $\kappa = \frac{\kappa_0}{P} \left(P - \alpha \cdot \left(c_p \cdot m \cdot \frac{\Delta T}{\Delta t} + P_{loss} \right) \right)$	0.2 pts
	Writing that $\alpha = 0.5$	0.3 pts
	κ range in $\left[W/(mK) \right]$: $376 \leq \kappa \leq 416$	0.3 pts
	$356 < \kappa < 376$ or $416 < \kappa < 436$	0.2 pts

Part D: Thermal conductivity of multiple metals (1.0 points)

D.1	Writing temperature with units	0.1 pts
D.2	Temperature measurements (0.2 pts)	
	Measurement time is greater than 15 minutes	0.1 pts
	Correct calculation of $\Delta T / \Delta x$ using $28mm$ spacing	0.1 pts
D.3	Calculation of κ for other metals (0.7 pts)	
	general form of $\kappa_\alpha = \kappa_{copper} \cdot \frac{Slope}{(\Delta T / \Delta x)_\alpha}$	0.1 pts
	Weighted average: 1:2 and 2:1 average between coppers (correct direction, see solution)	0.4 pts
	Weighted average but wrong weights	0.2 pts
	Slope from closest copper or simple average	0.1 pts
	$103\left[W/(mK)\right] \le \kappa_{brass} \le 126\left[W/(mK)\right]$	0.1 pts
	$215\left[W/(mK)\right] \le \kappa_{Aluminum} \le 263\left[W/(mK)\right]$	0.1 pts

Part E: The Wiedemann-Franz law (0.5 points)

E.1	Wiedemann-Franz law table (0.5 pts)	
	Calculation of Lorenz number, using absolute temperature	0.1 pts
	$2.12\left[W\Omega/K^2\right] \le L_{copper} \le 2.39\left[W\Omega/K^2\right]$	0.2 pts
	$2.13\left[W\Omega/K^2\right] \le L_{Brass} \le 2.71\left[W\Omega/K^2\right]$	0.1 pts
	$2.00\left[W\Omega/K^2\right] \le L_{Aluminum} \le 2.54\left[W\Omega/K^2\right]$	0.1 pts

Please note that this marking scheme might change, particularly the ranges.