$K(10\ K) \approx K_{el}(10\ K) = L\ \sigma_{el}\ T = 2.45 \cdot 10^{-8} W\ \Omega/K^2 \cdot 5.611 \cdot 10^9/(\Omega m) \cdot 10\ K = 1375\ W/(mK)$

And $K(100\ K) \approx 88.37\ W/(mK)$, $K(300\ K) \approx 74.24\ W/(mK)$

The carefully measured resistances of the platinum thermometer give an accurate measure of the free electron mean free path based on eqn. IIIE-21b. For platinum $n_\varepsilon = 2$, $\theta_F = 1.14 \cdot 10^5 K$, $\rho = 21.5\ g/cm^3$ and $M = 195.0\ kg/(kg\ mol)$. Thus,

$$V_F = \left(\frac{2k\theta_F}{m_e^*}\right)^{\frac{1}{2}} = \left[\frac{2 \cdot 1.380 \cdot 10^{-23} J/(part\ K) \cdot 1.14 \cdot 10^5 K}{9.109 \cdot 10^{-31} kg/elect}\right]^{\frac{1}{2}} = 1.86 \cdot 10^6 m/s$$

$$\lambda_{c,F}(10\ K) = \frac{\sigma_{el}(10\ K)\ m_e^*\ V_F M}{n_\varepsilon\ N_A\ \rho e^2}$$

$$= \frac{5.611 \cdot 10^9/(\ m) \cdot 9.109 \cdot 10^{-31} kg/elect \cdot 1.86 \cdot 10^6 m/s \cdot 195\ kg/(kg\ mol)}{2 \cdot 6.023 \cdot 10^{26} part/(kg\ mol) \cdot 21.3\ \ 10^3 kg/m^3 \cdot (1.602 \cdot 10^{-19} c)^2}$$

$$= 2.81 \cdot 10^{-6} m = 2.81 \cdot 10^4\ \mathring{A}$$

and

$\lambda_{c,F}(100\ K) = 181\ \mathring{A}$, $\lambda_{c,F}(300\ K) = 50.6\ \mathring{A}$.

Exercise 20. Nichrome is an alloy that is used extensively in resistance heating elements. At room temperature its conductivity is $9.7 \cdot 10^5/(\Omega m)$. Use the Wiedemann-Franz law to determine its thermal conductivity. Comment on the authenticity of this procedure for nichrome.

A comparison between Exmp. 9 and Exer. 20 illustrates the very large difference between the electrical conductivities of the relatively good conductor, platinum, and the poor conductor, nichrome. The Wiedemann-Franz law provides a convenient method of predicting the thermal conductivity of metals from rather easily obtained electric resistance data. However, this technique is not satisfactory for poor conductors; in poor conductors—metallic or semiconductor, lattice heat conduction is appreciable. In principle, eqn. IIIE-24b can be employed to determine the electrical conductivity of semiconductors. However, one must recognize that the free electron number density (or valence) of semiconductors is a variable. Indeed, in intrinsic semiconductors the variation of $n_{v,el}$ dominates the temperature dependence of the electrical conductivity. As a result σ_{el} increases with temperature for intrinsic semiconductors.

Ans. 20. $K \approx K_{el} = L\sigma_{el}T = 2.45 \cdot 10^{-8} W\Omega/K^2 \cdot 9.7 \cdot 10^5/(\Omega m) \cdot 300\ K = 7.13\ W/(mK)$.

The thermal conductivity is an order of magnitude less than that for platinum and nearly two orders of magnitude less than that for copper. The accuracy of the prediction is dependent on phonon heat conduction being negligible for nichrome. This is a questionable assumption.