

- 13.48) a) USING DRUDE'S FORMULA  $\sigma = \frac{ne^2\tau}{m}$  AND KNOWN CONDUCTIVITIES OF METALS, MAKE AN ORDER-OF-MAGNITUDE ESTIMATE OF THE COLLISION TIME,  $\tau$ .
- b) COMPUTE THE THERMAL SPEED OF  $e^-$  AT  $T_{\text{ROOM}}$ .
- c) COMPUTE THE MEAN-FREE PATH & COMPARE TO LATTICE SPACINGS  $\sim$  FEW TENTHS OF A NM. (cf p 429 EXAMPLE 13.3)

a) REARRANGING DRUDE'S EQUATION GIVES

$$\tau = \frac{m\sigma}{ne^2}, \quad n_{\text{Cu}} = 4 \times 10^{28} \text{ m}^{-3}$$

FOR Cu AT  $18^\circ\text{C}$ ,  $\sigma = 5.88 \times 10^7 (\Omega \cdot \text{m})^{-1}$ ,  $m = m_e$

$$\Rightarrow \tau_{\text{Cu}} = \frac{(9.11 \times 10^{-31} \text{ kg})(5.88 \times 10^7 (\Omega \cdot \text{m})^{-1})}{(4 \times 10^{28} \text{ m}^{-3})(1.602 \times 10^{-19} \text{ C})^2}$$

UNITS:  $\frac{\text{kg} \cdot \text{m}^3}{\Omega \cdot \text{m} \cdot \text{C}^2} \sim \frac{\text{kg} \cdot \text{m}^2}{\text{C}^2} \left( \frac{1}{\Omega} \right) \sim \left( \frac{\text{kg} \cdot \text{m}^2}{\text{C}^2} \right) \left( \frac{\text{S} \cdot \text{C}^2}{\text{kg} \cdot \text{m}^2} \right) \sim \text{S}!$

$V = RI \Rightarrow \Omega = \frac{\text{VOLTS}}{\text{AMP}} \sim \left( \frac{\text{N} \cdot \text{m}}{\text{C}} \right) \left( \frac{\text{C}}{\text{C}} \right) \sim \left( \frac{\text{kg} \cdot \text{m}}{\text{S}^2} \right) \left( \frac{\text{m} \cdot \text{S}}{\text{C}^2} \right) \sim \frac{\text{kg} \cdot \text{m}^2}{\text{S} \cdot \text{C}^2}$

$V = ED = \frac{E}{q} D \sim \frac{\text{N} \cdot \text{m}}{\text{C}}$

$$\Rightarrow \tau_{\text{Cu}} = 5.22 \times 10^{-14} \text{ s}$$

b) FOR A CLASSICAL GAS AT  $18^\circ\text{C}$

$$\frac{1}{2} m \overline{v^2} = \frac{3}{2} kT$$

$$v_{\text{rms}} = \sqrt{\frac{3kT}{m_e}} = \sqrt{\frac{3(1.38 \times 10^{-23} \text{ J/K})(291 \text{ K})}{9.11 \times 10^{-31} \text{ kg}}} = 1.16 \times 10^5 \frac{\text{m}}{\text{S}}$$

c) THE MEAN-FREE PATH IS

$$\lambda_{\text{mfp}} = v_{\text{rms}} \tau_{\text{Cu}} = (1.16 \times 10^5) (5.22 \times 10^{-14})$$

$$\lambda_{\text{mfp}} = 6.06 \times 10^{-9} = 6.06 \text{ nm}$$

$\Rightarrow$  Cu's MEAN FREE PATH IS ABOUT 6 nm  
 II INTERATOMIC SPACING IS ABOUT 0.3 nm

$\Rightarrow$  DRUDE'S ESTIMATE OF THE MEAN-FREE-PATH WAS ABOUT 10 TIMES TOO SMALL  
 AND HIS ESTIMATION OF THE SPEED WAS 10 TIMES TOO SMALL. SO EINSTEIN THREW IN 100!