

# Exam Winter Semester 2022

## Student Group

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### Exercise E1 Resistivity and temperature dependent Resistance (written test, approx. 7 % of a 60-minute written test, SS2023)

The conductivity of a dielectric material is described by the Arrhenius law:  $\sigma = \sigma_0 \exp(-E_a/kT)$  with  $\sigma_0 = 10^{17} \text{ S/m}$  and  $E_a = 0.8 \text{ eV}$ . The resistivity of the dielectric material is  $\rho(20 \text{ }^\circ\text{C}) = 10^{17} \text{ } \Omega\text{m}$ . The temperature coefficients in the range  $20 \text{ }^\circ\text{C}$  and  $55 \text{ }^\circ\text{C}$  are given as  $\alpha = -0.048 \text{ } 1/\text{K}$  and  $\beta = +0.00057 \text{ } 1/\text{K}^2$ .

**Solution**  
 The resistivity of the dielectric material is  $\rho(20 \text{ }^\circ\text{C}) = 10^{17} \text{ } \Omega\text{m}$ .

$$\begin{aligned} \rho(55 \text{ }^\circ\text{C}) &= \rho(20 \text{ }^\circ\text{C}) \cdot (1 + \alpha \cdot \Delta T + \beta \cdot T^2 + \dots) \\ \rho(55 \text{ }^\circ\text{C}) &= 10^{17} \text{ } \Omega\text{m} \cdot (1 - 0.048 \text{ } 1/\text{K} \cdot (35 \text{ }^\circ\text{C}) + 0.00057 \text{ } 1/\text{K}^2 \cdot (35 \text{ }^\circ\text{C})^2) \end{aligned}$$

Calculate the resistance for the dielectric material for  $20 \text{ }^\circ\text{C}$ .

Solution

$$\begin{aligned} R(20 \text{ }^\circ\text{C}) &= \rho \cdot \frac{d}{A} \\ &= 10^{17} \text{ } \Omega\text{m} \end{aligned}$$

$$I = \frac{U}{R} = \frac{0.8 \cdot 10^{-6} \cdot 1.80}{1.10 \cdot 10^{-6}} \approx 1.36 \text{ A}$$

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**Exercise E4 Resistance of a Wire by Resistivity**  
**(written test, approx. 6 % of a 60-minute written test, WS2022)**

A heating element made of nichrome wire with a temperature coefficient of \$1.80 \cdot 10^{-5} \text{ K}^{-1}\$ is used. The electric power dissipation (= heat flow) of \$P=40 \text{ W}\$ is necessary. Calculate the current \$I\$ and the operating voltage \$U\$ for heating elements. The Nichrome wire has a resistivity of \$1.10 \cdot 10^{-6} \text{ } \Omega \cdot \text{m}\$.

The heating element is \$3 \text{ m}\$ long and has a diameter of \$3.57 \text{ mm}\$.  
 Solution: Calculate the resistance \$R\$ of the heating element.

Solution

$$P = U \cdot I = R \cdot I^2 \quad \rightarrow \quad I = \sqrt{\frac{P}{R}} = \sqrt{\frac{40 \text{ W}}{0.33 \text{ } \Omega}} \approx 11.0 \text{ A}$$

$$R = \rho \cdot \frac{l}{A} \quad | \quad A = r^2 \cdot \pi = \frac{1}{4} d^2 \cdot \pi \quad \parallel \quad R = \rho \cdot \frac{4 \cdot l}{d^2 \cdot \pi} \quad \parallel \quad R = 1.10 \cdot 10^{-6} \text{ } \Omega \cdot \text{m} \cdot \frac{4 \cdot 3 \text{ m}}{(3.57 \cdot 10^{-3} \text{ m})^2 \cdot \pi} \approx 0.33 \text{ } \Omega$$

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**Exercise E1 Resistivity and temperature dependent Resistance**  
**(written test, approx. 7 % of a 60-minute written test, SS2023)**

The conductivity \$\sigma\$ of a dielectric material is described by the Arrhenius law: \$\sigma = \sigma\_0 \cdot \exp(-E\_a / (k\_B \cdot T))\$. The conductivity is \$1.0 \text{ S/m}\$ at \$20 \text{ }^\circ\text{C}\$ and \$100 \text{ S/m}\$ at \$55 \text{ }^\circ\text{C}\$. Calculate the activation energy \$E\_a\$ and the pre-exponential factor \$\sigma\_0\$.

Solution

The resistivity of the dielectric material is \$\rho\_{PP}(20 \text{ }^\circ\text{C}) = 10^{17} \text{ } \Omega \cdot \text{m}\$.

$$R(50 \text{ }^\circ\text{C}) = \frac{1}{\sigma(50 \text{ }^\circ\text{C})} = \frac{1}{80 \text{ S/m}} = 0.0125 \text{ } \Omega$$

for the given material the temperature coefficients in the range \$20 \text{ }^\circ\text{C}\$ and \$55 \text{ }^\circ\text{C}\$ are given as \$\alpha = -0.048 \text{ } 1/\text{K}\$ and \$\beta = +0.00057 \text{ } 1/\text{K}^2\$.

$$R(55 \text{ }^\circ\text{C}) = R(20 \text{ }^\circ\text{C}) \cdot (1 + \alpha \cdot \Delta T + \beta \cdot T^2 + \dots) = 80 \text{ } \Omega \cdot (1 - 0.048 \text{ } 1/\text{K} \cdot (35 \text{ K}) + 0.00057 \text{ } 1/\text{K}^2 \cdot (35 \text{ K})^2)$$

Calculate the resistance for the dielectric material for  $20 \text{ }^\circ\text{C}$ .

Solution

$$R(20 \text{ }^\circ\text{C}) = \rho \cdot \frac{d}{A} = 10^{17} \frac{\Omega \cdot \text{m}}{1 \text{ m}^2} \cdot \{0.8 \cdot 10^{-6} \text{ m}\}$$

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**Exercise E1 Resistance of a Wire by Resistivity  
(written test, approx. 6 % of a 60-minute written test, WS2022)**

**Result**

A minimum power dissipation (= heat flow) of  $P=40 \text{ W}$  is necessary.  
 Calculate the minimum resistance  $R$  of the heating element.  
 The Nichrome wire has a resistivity of  $1.10 \cdot 10^{-6} \text{ } \Omega \text{ m}$ .  
 The heating element is  $3 \text{ m}$  long and has a diameter of  $3.57 \text{ mm}$ .  
 1. Calculate the resistance  $R$  of the heating element.

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Solution
\begin{align*} P &= U \cdot I = R \cdot I^2 \quad \rightarrow \quad I = \\ &= \sqrt{\frac{P}{R}} = \sqrt{\frac{40 \text{ W}}{0.33 \text{ } \Omega}} \end{align*}

\begin{align*} R &= \rho \cdot \frac{l}{A} \quad | \quad \text{with } A = r^2 \cdot \pi = \\ &= \frac{1}{4} d^2 \cdot \pi \quad || \quad R = \rho \cdot \frac{l}{\frac{1}{4} d^2 \cdot \pi} \quad || \quad R = \\ &= 1.10 \cdot 10^{-6} \text{ } \Omega \text{ m} \cdot \frac{4 \cdot 3 \text{ m}}{(3.57 \cdot 10^{-3} \text{ m})^2 \cdot \pi} \quad || \quad \end{align*}
  
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