

Exam Winter Semester 2022

Student Group

First Name	Surname	Matrikel Nr.

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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: $\rho = \rho_0 \cdot \exp(-E_a / (k_B \cdot T))$. The activation energy E_a is given as 0.8 eV . The pre-exponential factor ρ_0 is given as $10^{17} \text{ } \Omega^{-1} \text{ m}^{-1}$. The temperature T is given as $20 \text{ } ^\circ\text{C}$ and $55 \text{ } ^\circ\text{C}$.

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

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 $\beta = +0.00057 \text{ } 1/\text{K}^2$.

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

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

Solution

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

$$I = \frac{0.8 \cdot 10^{-6} \cdot V}{1 \cdot 10^{-2}} \quad \text{align*}$$

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Exercise E1 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: $R = 10^{-3} \text{ } \Omega$
 .. Calculate the resistance \$R\$ of the heating element.

Solution

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

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

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Exercise E2 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: $\sigma = \sigma_0 \cdot \exp(-\frac{E_a}{kT})$. 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\$ in \$\text{eV}\$.

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

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

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

Solution

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

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

2. The temperature coefficient of resistance of a wire is $\alpha = 1.80 \text{ }^\circ\text{C}^{-1}$. The electric
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 m long and has a diameter of 3.57 mm .
 1. Calculate the resistance R of the heating element.

Solution

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

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

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