

Exam Winter Semester 2022

Student Group

First Name	Surname	Matrikel Nr.

Table of Contents

Exercise E1 Resistivity and temperature dependent Resistance (written test, approx. 7 % of a 60-minute written test, SS2023) 2

Exercise E1 Resistance of a Wire by Resistivity (written test, approx. 6 % of a 60-minute written test, WS2022) 3

Exercise E2 Resistivity and temperature dependent Resistance (written test, approx. 7 % of a 60-minute written test, SS2023) 3

Exercise E1 Resistance of a Wire by Resistivity (written test, approx. 6 % of a 60-minute written test, WS2022) 4

**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: $\sigma = \sigma_0 \exp(-E_a/kT)$ where σ_0 is a constant, E_a is the activation energy, k is the Boltzmann constant, and T is the absolute temperature. The resistivity of the dielectric material is $\rho = 10^{17} \Omega \cdot \text{m}$ at $T = 20^\circ\text{C}$ and $\rho = 80 \text{ G}\Omega \cdot \text{m}$ at $T = 55^\circ\text{C}$. The temperature coefficients in the range 20°C to 55°C are given as $\alpha = -0.048 \text{ 1/K}$ and $\beta = +0.00057 \text{ 1/K}^2$.

Solution
The resistivity of the dielectric material is $\rho(T) = 10^{17} \Omega \cdot \text{m} \cdot \exp(\alpha \Delta T + \beta \Delta T^2)$.

$$\begin{aligned} \rho(55^\circ\text{C}) &= \rho(20^\circ\text{C}) \cdot (1 + \alpha \Delta T + \beta \Delta T^2) \\ 80 \text{ G}\Omega \cdot \text{m} &= 10^{17} \Omega \cdot \text{m} \cdot (1 - 0.048 \text{ 1/K} \cdot (35 \text{ K}) + 0.00057 \text{ 1/K}^2 \cdot (35 \text{ K})^2) \end{aligned}$$

Calculate the resistance for the dielectric material for 20°C .

Solution

$$\rho(20^\circ\text{C}) = \rho_0 \cdot \exp(\alpha \Delta T + \beta \Delta T^2) = 10^{17} \Omega \cdot \text{m}$$

$$I = \frac{P}{U} = \frac{40 \text{ W}}{230 \text{ V}} \approx 0.174 \text{ A}$$

resistivity, power, exam ee1 ss2023

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. An 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: $R = 1.10 \cdot 10^{-6} \text{ } \Omega \cdot \text{m} \cdot \frac{4 \cdot 3 \text{ m}}{(3.57 \cdot 10^{-3} \text{ m})^2 \cdot \pi}$

Solution

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

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

resistivity, power, exam ee1 ws2022

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\$ 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}\$.

$$\rho_{PP}(20 \text{ }^\circ\text{C}) = 10^{17} \text{ } \Omega \cdot \text{m} \quad | \quad \rho_{PP}(55 \text{ }^\circ\text{C}) = 10^{15} \text{ } \Omega \cdot \text{m}$$

$$\ln\left(\frac{\rho_{PP}(55 \text{ }^\circ\text{C})}{\rho_{PP}(20 \text{ }^\circ\text{C})}\right) = \ln\left(\frac{10^{15}}{10^{17}}\right) = -2 = \alpha \cdot \Delta T + \beta \cdot (\Delta T)^2$$

$$-2 = -0.048 \cdot (35 \text{ K}) + 0.00057 \cdot (35 \text{ K})^2$$

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

Solution

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

[resistivity, power, exam ee1 ss2023](#)

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

2. Heating a wire leads to an increase in its resistance. A wire with a cross-section of 1.80 mm^2 and a length of 1.00 m is made of a material with a resistivity of $1.80 \cdot 10^{-8} \Omega \cdot \text{m}$ at $20 \text{ }^\circ\text{C}$. The wire is heated to $100 \text{ }^\circ\text{C}$. Calculate the resistance of the wire at $100 \text{ }^\circ\text{C}$.

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 $1.10 \cdot 10^{-6} \text{ } \Omega \cdot \text{m}$.
 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

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

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

resistivity, power, exam ee1 ws2022

From:
<https://wiki.mexle.org/> - **MEXLE Wiki**

Permanent link:
https://wiki.mexle.org/electrical_engineering_1/ws2022_exam?rev=1676153022

Last update: **2023/02/11 23:03**

