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 resistivity of a dielectric material is described by the Result

between the plates of $d=0.8 ~\rm mm$ and $A=100 ~\rm cm^2$ is $R(25 ~\rm °C) = 15 ~\rm G\Omega$.

Solution

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

for the given material the temperature coefficients in the range of $20 ~\rm °C$ and $55 ~\rm °C$ are given as $\alpha =-0.048 ~\rm 1/K$ and $\beta=+0.00057 ~\rm 1/K^2$.

$$\begin{align*} R(55 ~\rm °C) &= R(20 ~\rm °C) \cdot (1+\alpha\cdot\Delta T + \beta\cdot T^2 + ...)\\ &= 80 ~\rm G\Omega \cdot (1-0.048 ~\rm 1/K \cdot(35 ~{\rm K}) + 0.00057 ~\rm 1/K^2\cdot\Delta (35 ~{\rm K})^2) \end{align*}$$

Calculate the resistance for the dielectric material for $20 ~\rm °C$.

Solution

$$\begin{align*} R(20 ~\rm °C) &= \rho\cdot {{d}\over{A}}\\ &= 10^{17} ~\Omega$$

\rm m \cdot {{0.8\cdot 10^{-6} ~\rm m}\over{1 ~\rm m^2}} \end{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 is made of a Nichrome wire with a round cross-section ($\rightarrow$ technical drawing). For the heating element a power dissipation (= heat flow) of $P=40 ~\rm{W}$ is necessary.
Nichrome is a common Nickel-Chromium alloy for heating elements.
The Nichrome wire has a resistivity of $1.10\cdot 10^{-6} ~\Omega \rm{m}$.
The heating element is $3 ~\rm{m}$ long and has a diameter of $3.57 ~\rm{mm}$.
1. Calculate the resistance R of the heating element.

Result
Calculate the current I needed to operate the heating element.

Solution
\begin{align*} R = 1.10\cdot 10^{-6} ~\Omega \rm{m} \cdot \frac{3 ~\rm{m}}{\pi \cdot (1.785\cdot 10^{-3} ~\rm{m})^2} = 0.33 ~\Omega \end{align*}

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

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

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

The resistivity of a dielectric material is described by the Pearson equation. For $T=20 ~\rm °C$ the resistivity is $\rho_{\rm PP}(20 ~\rm °C)=10^{17} ~\Omega \rm m$.
For the given material the temperature coefficients in the range of $20 ~\rm °C$ and $55 ~\rm °C$ are given as $\alpha =-0.048 ~\rm 1/K$ and $\beta=+0.00057 ~\rm 1/K^2$.
Between two plates of the dielectric material a resistance of $R(20 ~\rm °C) = 80 ~\rm G\Omega$ is measured.
The resistance of the dielectric material is to be calculated for a temperature of $T=55 ~\rm °C$.

Result
The resistance of the dielectric material at $T=55 ~\rm °C$ is calculated by the given approximation formula to $R(55 ~\rm °C) = 15.00 ~\rm G\Omega$.

Solution
\begin{align*} R(55 ~\rm °C) &= 80 ~\rm G\Omega \cdot (1-0.048 ~\rm 1/K \cdot(35 ~{\rm K}) + 0.00057 ~\rm 1/K^2\cdot\Delta (35 ~{\rm K})^2) \\ &= 15.00 ~\rm G\Omega \end{align*}

\begin{align*} R(55 ~\rm °C) &= R(20 ~\rm °C) \cdot (1+\alpha\cdot\Delta T + \beta\cdot T^2 + ...)\\ &= 80 ~\rm G\Omega \cdot (1-0.048 ~\rm 1/K \cdot(35 ~{\rm K}) + 0.00057 ~\rm 1/K^2\cdot\Delta (35 ~{\rm K})^2) \end{align*}

Calculate the resistance for the dielectric material for $20 ~\rm °C$.

Solution

$$\begin{align*} R(20 ~\rm °C) &= \rho\cdot {{d}\over{A}}\\ &= 10^{17} ~\Omega \rm m \cdot {{0.8\cdot 10^{-6} ~\rm m}\over{1 ~\rm m^2}} \end{align*}$$

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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 heating element is a Nichrome wire with a cross-section of $1.0 ~\rm mm^2$.
3. The heating element is used to heat water with a temperature of $180 ~\rm °C$.
4. Electric Result

a) Is a power dissipation (= heat flow) of $P=40 ~\rm{W}$ necessary.
b) Calculate the current I and the resistance R for heating elements.
The Nichrome wire has a resistivity of $1.10\cdot 10^{-6} ~\Omega \rm{m}$.
The heating element is $3 ~\rm{m}$ long and has a diameter of $3.57 ~\rm{mm}$.

Solution
1. Calculate the resistance R of the heating element.

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

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

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