

task_k4wrrhf8v46gct49_with_calculation

Student Group

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Exercise E1 Capacitor

(written test, approx. 12 % of a 120-minute written test, SS2024)

0. Calculate the change of capacitance if the dielectric is replaced by a plate capacitor with a dielectric constant $\epsilon_r = 2.3$. Results are applied.

The contaminant has $\epsilon_{\text{r,c}} > \epsilon_{\text{r,air}}$, while the distance between the plates remains the same. Give a generalized formula

Path 1
 $C = f(A, d, x, \epsilon_{\text{r,c}}, \epsilon_{\text{r,air}})$.
 $Q = \frac{U}{\frac{1}{\epsilon_0 \epsilon_{\text{r,c}}} \frac{A}{d-x} + \frac{1}{\epsilon_0 \epsilon_{\text{r,air}}} \frac{x}{d}}$
 Path 2
 here are two ways now. Either: $Q = C \cdot U = 1.1 \cdot 10^{-6} \text{ F} \cdot 3.3 \text{ V} = 3.63 \cdot 10^{-6} \text{ C}$ Or: $Q = D \cdot A = 146 \cdot 10^{-6} \text{ C/m}^2 \cdot 25 \cdot 10^{-6} \text{ m}^2 = 3.65 \cdot 10^{-6} \text{ C}$
 The displacement field is given by: $D = \epsilon_0 \epsilon_{\text{r}} E$
 $E = \frac{U}{d} = \frac{3.3 \text{ V}}{200 \cdot 10^{-6} \text{ m}} = 1.65 \cdot 10^7 \text{ V/m}$
 The resulting capacitance is now a series circuit of C_{air} and C_{c} .
 Therefore: $C = \frac{1}{\frac{1}{C_{\text{air}}} + \frac{1}{C_{\text{c}}}}$

With $C_{\text{air}} = \epsilon_0 \epsilon_{\text{r,air}} \frac{A}{d}$ and $C_{\text{c}} = \epsilon_0 \epsilon_{\text{r,c}} \frac{A}{d-x}$
 $C = \frac{\epsilon_0 A}{d} \left(\frac{\epsilon_{\text{r,c}}}{d-x} + \frac{\epsilon_{\text{r,air}}}{x} \right)$

In the following such a sensor is given with:

This leads to: $C = \epsilon_0 A \left(\frac{\epsilon_{\text{r,c}}}{d-x} + \frac{\epsilon_{\text{r,air}}}{x} \right)$

- Plate area: $A = 25 \cdot 10^{-6} \text{ m}^2$
- Distance between both plates: $d = 200 \cdot 10^{-6} \text{ m}$
- Air between the plates: $\epsilon_{\text{r,air}} = 1$
- Supply voltage: $U = 3.3 \text{ V}$
- Boundary effects on the end of the layers shall be ignored in the following calculations.

$\epsilon_0 = 8.854 \cdot 10^{-12} \text{ F/m}$

1. Calculate the capacity C .

Path

$C = \epsilon_0 A \left(\frac{\epsilon_{\text{r,c}}}{d-x} + \frac{\epsilon_{\text{r,air}}}{x} \right) = 8.854 \cdot 10^{-12} \cdot 25 \cdot 10^{-6} \left(\frac{2.3}{200 \cdot 10^{-6} - x} + \frac{1}{x} \right)$

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