

task_k4wrrhf8v46gct49_with_calculation

Student Group

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Exercise E3 Capacitor

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

0. Calculate the change of capacitance if the insulator is replaced by paper (dielectric constant $\epsilon_r = 2.3$). Results are applied.

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

Path

$$C = \frac{Q}{U} = \frac{\epsilon_0 \epsilon_r \frac{A}{d} U}{U} = \epsilon_0 \epsilon_r \frac{A}{d}$$

Path

$$C = \frac{Q}{U} = \frac{\epsilon_0 \epsilon_r \frac{A}{d-x} U + \epsilon_0 \epsilon_{r,c} \frac{A}{x} U}{U} = \epsilon_0 \left(\epsilon_r \frac{A}{d-x} + \epsilon_{r,c} \frac{A}{x} \right)$$

Path

There are two ways now. Either: $Q = C \cdot U = 1.1 \cdot 10^{-6} \text{ C}$ Or: $Q = D \cdot A = 146 \cdot 10^{-6} \text{ C}$

The displacement field is given by: $D = \epsilon_0 \epsilon_r E = \epsilon_0 \epsilon_r \frac{U}{d}$ and $E = \frac{U}{d}$

The resulting capacity C is now a series circuit of C_{air} and C_c .

Therefore: $C = \frac{1}{\frac{1}{C_{air}} + \frac{1}{C_c}}$

With $C_{air} = \epsilon_0 \epsilon_r \frac{A}{d-x}$ and $C_c = \epsilon_0 \epsilon_{r,c} \frac{A}{x}$

$$C = \frac{1}{\frac{1}{\epsilon_0 \epsilon_r \frac{A}{d-x}} + \frac{1}{\epsilon_0 \epsilon_{r,c} \frac{A}{x}}} = \frac{\epsilon_0 A}{\frac{d-x}{\epsilon_r} + \frac{x}{\epsilon_{r,c}}}$$

- In the following such a sensor is given with:
- Plate area: $A = 25 \text{ mm}^2$
 - Distance between both plates: $d = 200 \text{ }\mu\text{m}$
 - Air between the plates: $\epsilon_{r,air} = 1$
 - 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

$$C = \frac{\epsilon_0 \epsilon_r A}{d-x} = \frac{8.854 \cdot 10^{-12} \cdot 25 \cdot 10^{-6}}{200 \cdot 10^{-6}} = 1.10675 \cdot 10^{-12} \text{ F}$$

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