

task_y7dozgdsljqvnqge_with_calculation

Student Group

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Exercise E1 Capacitor

(written test, approx. 7 % of a 120-minute written test, SS2022)

Calculate the capacitance of the capacitor shown in the picture, with the following dimensions: $w = 0.1 \text{ mm}$ of air ($\epsilon_r = 1$), while the thickness of the dielectric material remains the same.

Length of layer overlap: $l = 1.5 \text{ mm}$

Distance between single layers: $d = 1.0 \text{ }\mu\text{m}$

- Depth of component: $w = 0.7 \text{ mm}$

Number of layers (from the picture): 3 left-side and 3 right-side layers.

The capacity can be derived from the geometry by:
$$C = \epsilon_0 \epsilon_r \frac{A}{d}$$

The air is another capacitor in series to the dielectric material. Therefore, the capacity can be calculated as
$$\frac{1}{C_{\text{total}}} = \frac{1}{C_{\text{dielectric}}} + \frac{1}{C_{\text{air}}}$$

The capacity of air is
$$C_{\text{air}} = \epsilon_0 \epsilon_r \frac{N \cdot l \cdot w}{d}$$

$$= 8.854 \cdot 10^{-12} \cdot 1 \cdot \frac{5 \cdot 1.5 \cdot 10^{-3} \cdot 0.7 \cdot 10^{-3}}{0.1 \cdot 10^{-6}} = 0.465 \text{ nF}$$

The material shall have a dielectric permittivity of $\epsilon_r = 3$.

The following calculation shall ignore boundary effects on the end of the layers.

$$\frac{1}{C_{\text{total}}} = \frac{1}{0.139 \text{ nF}} + \frac{1}{0.465 \text{ nF}}$$

For this, we have to count facing areas A_0 . There are $N = 5$.

What is the field strength in the dielectric material between the layer, when a voltage of $U = 6.3 \text{ V}$ is applied?

The electric field strength E is given by:
$$E = \frac{U}{d} = \frac{6.3 \text{ V}}{1 \cdot 10^{-6} \text{ m}}$$

Therefore, the formula is
$$C = \frac{\epsilon_0 \epsilon_r \{N \cdot l \cdot w\}}{d} \approx 8.854 \cdot 10^{-12} \frac{\text{As/Vm} \cdot 3 \cdot \{5 \cdot 1.5 \cdot 10^{-3} \text{ m} \cdot 0.7 \cdot 10^{-3} \text{ m}\}}{1 \cdot 10^{-6} \text{ m}}$$

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