task_ddjurcpk494go2q1_with_calculation

Student Group

First Name	Surname	Matrikel Nr.

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electric field, magnetic field, exam ee2 SS2024

Exercise E1 Capacitor
(written test, approx. 12 % of a 120-minute written test, SS2024)

1. What is the magnitude of the electric displacement field D at $\rm (0.1 ~mm | 0)$ and $\rm (0.55 ~mm | 0)$? The diagram shows the cross-section of a coaxial cable with the origin in the center of the diagram. Use proper dimensions and labels for the diagram! The following situation appears:

2. Plot the graph of the magnitude of $H(x)$ in the range $[-0.6 ~\rm mm, +0.6 ~\rm mm]$.

Result

- Inner conductor: $+3.3 ~\rm mA$, $+10 ~\rm nC$ (current into the plane of the diagram)
- Outer conductor: $-3.3 ~\rm mA$, $ 0 ~\rm nC$ (current out of the plane of diagram)

Path

Path

- for $(0.1 ~\rm mm | 0)$: $D_{\rm i} = 3.18... ~\rm µC/m^2$ / $H = 5.25... ~\rm A/m$
- for $(0.55 ~\rm mm| 0)$: $D_{\rm o} = 0.579... ~\rm µC/m^2$ / $H = 0.955... ~\rm A/m$

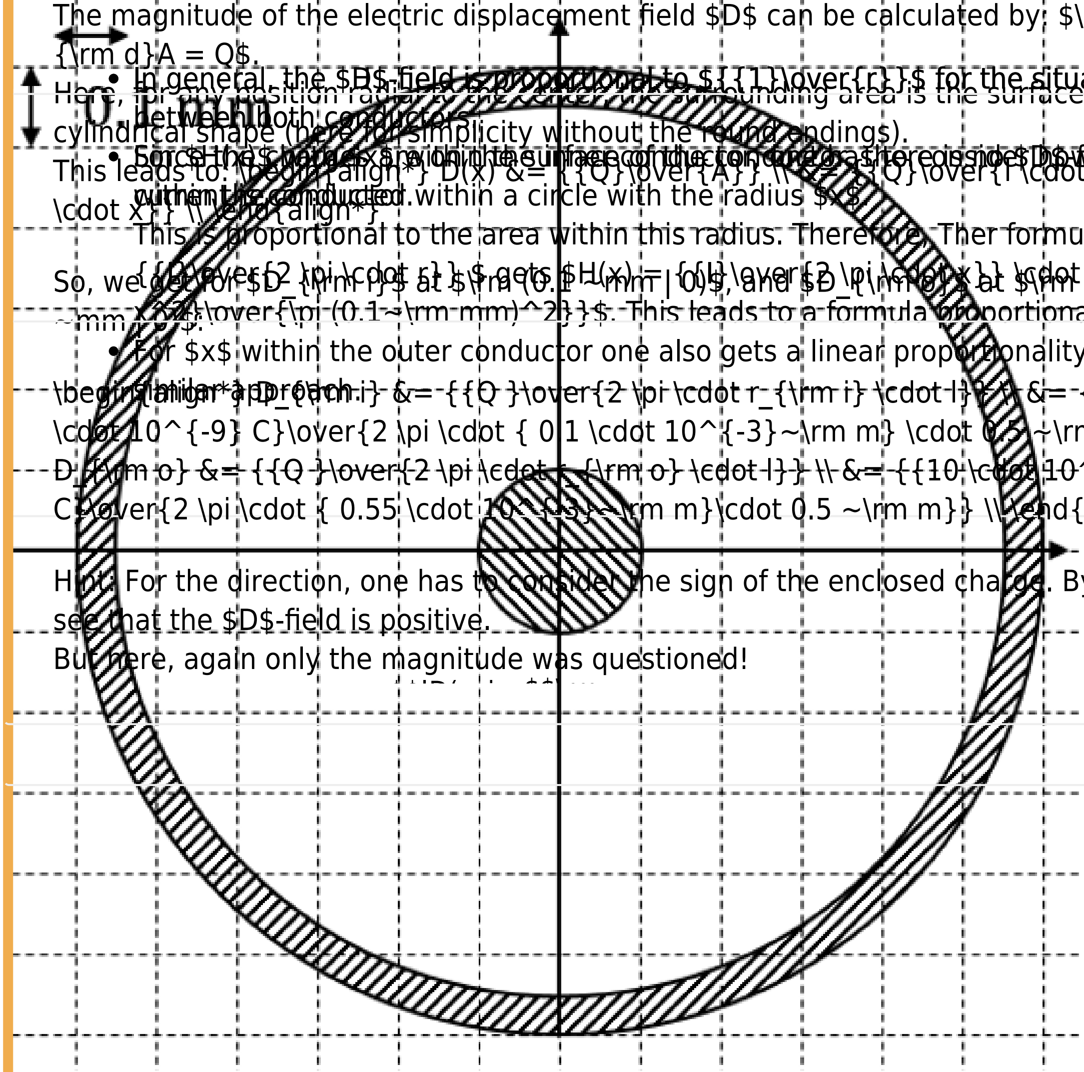
The magnitude of the electric displacement field D can be calculated by: $\int D {\rm d}A = Q$.
Here, for any position radial to the center, the surrounding area is the surface of a cylindrical shape (here for simplicity without the round endings).
This leads to: $\begin{align*} D(x) &= {{Q}\over{A}} \\ &= {{Q}\over{l \cdot 2\pi \cdot x}} \\ \end{align*}$

So, we get for $D_{\rm i}$ at $\rm (0.1 ~mm | 0)$, and $D_{\rm o}$ at $\rm (0.55 ~mm | 0)$:

$\begin{align*} D_{\rm i} &= {{Q }\over{2 \pi \cdot r_{\rm i} \cdot l}} \\ &= {{10 \cdot 10^{-9} C}\over{2 \pi \cdot { 0.1 \cdot 10^{-3}~\rm m} \cdot 0.5 ~\rm m}} \\ D_{\rm o} &= {{Q }\over{2 \pi \cdot r_{\rm o} \cdot l}} \\ &= {{10 \cdot 10^{-9} C}\over{2 \pi \cdot { 0.55 \cdot 10^{-3}~\rm m}\cdot 0.5 ~\rm m}} \\ \end{align*}$

Hint: For the direction, one has to consider the sign of the enclosed charge. By this, we see that the D-field is positive.
But here, again only the magnitude was questioned!

- In general, the H-field is proportional to ${{1}\over{r}}$ for the situation between both conductors.
- For x values within the inner conductor the current is not the full current, but only the current within a circle with the radius x. This is proportional to the area within this radius. Therefore, Ther formula $H = {{I}\over{2 \pi \cdot r}} $ gets $H(x) = {{I}\over{2 \pi \cdot x}} \cdot {{\pi x^2}\over{\pi (0.1~\rm mm)^2}}$. This leads to a formula proportional to x.
- Since the charges are on the surface of the conductor, there is no D-field within the conductor.
- For x within the outer conductor one also gets a linear proportionality with a similar approach.



1. What is the magnitude of the magnetic field strength H at $\rm (0.1 ~mm | 0)$ and $\rm (0.55 ~mm | 0)$?

Path

The magnitude of the magnetic field strength H can be calculated by: $H = {{I}\over{2 \pi \cdot r}} $
So, we get for $H_{\rm i}$ at $\rm (0.1 ~mm | 0)$, and $H_{\rm o}$ at $\rm (0.55 ~mm | 0)$:

\begin{align*} H_{\rm i} &= {{I}\over{2 \pi \cdot r_{\rm i}}} \\ &= {{+3.3 A}\over{2 \pi \cdot { 0.1 \cdot 10^{-3}~\rm m}}} \\ H_{\rm o} &= {{I}\over{2 \pi \cdot r_{\rm o}}} \\ &= {{+3.3 A}\over{2 \pi \cdot { 0.55 \cdot 10^{-3}~\rm m}}} \\ \end{align*}

Hint: For the direction, one has to consider the right-hand rule. By this, we see that the H-field on the right side points downwards.
Therefore, the sign of the H-field is negative.
But here, only the magnitude was questioned!