task_elndbo3xwi2klxuu_with_calculation

Student Group

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lorentz force, exam ee2 SS2021

Exercise E1 Lorentz Force (hard!)
(written test, approx. 10 % of a 120-minute written test, SS2021)

A 300-turn loop, suspended by a high-voltage line, carries a current of 1 A. The dimensions are shown in the figure. A homogeneous geomagnetic field is assumed. The magnetic field strength has a vertical component of $B_{\rm v} = 40 ~\rm \mu T$ and a horizontal component of $B_{\rm h} = 20 ~\rm \mu T$.
The angle between the transmission line and the horizontal component of the field strength is $\alpha = 20°$.
The picture on the right shows the line (black), the field strength components, and the angle in front and top view for illustration purposes.

A) 300-turn loop, suspended by a high-voltage line, carries a current of 1 A. The dimensions are shown in the figure. A homogeneous geomagnetic field is assumed. The magnetic field strength has a vertical component of $B_{\rm v} = 40 ~\rm \mu T$ and a horizontal component of $B_{\rm h} = 20 ~\rm \mu T$.
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Top View

Path

a) Calculate the force that results from the current flow on the entire conductor.
First, calculate the vertical and horizontal components and combine them accordingly.

Path

For the resulting current the direction of the path has to be considered with the right-hand rule:

- $I_{(1)} = +I_2 - I_1 - I_3 \quad \rightarrow \quad \theta_{(1)} = 2 {~\rm A} - 5 {~\rm A} - 1 {~\rm A} $
- $I_{(2)} = +I_3 + I_4 - I_1 \quad \rightarrow \quad \theta_{(2)} = 1 {~\rm A} + 4 {~\rm A} - 5 {~\rm A} $

The force on the transmission line can be calculated via the Lorentz force $\vec{F}_\rm L$: $\begin{align*} \vec{F} = I \cdot (\vec{l} \times \vec{B}) \end{align*}$

\end{align*} I_{(3)} = +I_3 - I_4 - I_2 \quad \rightarrow \quad \theta_{(3)} = 1 {~\rm A} - 4 {~\rm A} - 2 {~\rm A} $

Here, we have two components for the current - and therefore for the force - to evaluate.
Considering the right-hand rule (and the cross product), the vertical field $B_{\rm v}$ generates a horizontal force $F_{\rm h}$ and vice versa.

The horizontal component is given by \begin{align*} F_{\rm h} = I \cdot (l \cdot B_{\rm v}) \end{align*}