

task_elndbo3xwi2klxuu_with_calculation

Student Group

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**Exercise E9 Lorentz Force (hard!)
(written test, approx. 10 % of a 120-minute written test, SS2021)**

A) ~~300 picture below shows a straight high voltage direct current transmission line with a current of $I = 2000 \text{ A}$ on the left. As a result of the Lorentz force, the line is deflected downwards. A homogeneous geomagnetic field is assumed. The magnetic field strength has a vertical component of $B_{\text{v}} = 40 \text{ } \mu\text{T}$ and a horizontal component of $B_{\text{h}} = 20 \text{ } \mu\text{T}$. The angle between the transmission line and the horizontal component of the field strength is $\alpha = 20^\circ$. The picture on the right shows the line (black), the field strength components, and the angle in front and top view for illustration purposes.~~

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

- The horizontal component \vec{F}_{h} of the force is based on the vertical component \vec{B}_{v} of the magnetic field.
- The vertical component \vec{B}_{v} of the magnetic field is not shown in the image but is pointing into the ground.
- It has to be perpendicular to \vec{B}_{v} and to \vec{I} . The right-hand rule has to be applied.

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

\end{align*}

Here, we have two components for the current - and therefore for the force - to evaluate.

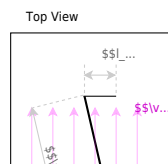
Considering the right-hand rule (and the cross product), the vertical field B_{v} generates a horizontal force F_{h} and vice versa.

The **horizontal component** is given by

$$\begin{aligned} F_{\text{h}} &= l \cdot (l \cdot B_{\text{v}}) \cdot 1'200 \cdot 300 \\ &\cdot 10^3 \cdot 40 \cdot 10^{-6} \cdot \frac{V_s}{m^2} = 14'400 \cdot \frac{V_s}{m} \\ &= 14'400 \cdot \frac{W_s}{m} = 14'400 \cdot N \end{aligned}$$

For the **vertical component** the angle α has to be considered.

For the maximum F_{v} the angle α has to be 90° , therefore the \sin has to be used.



$$\begin{aligned} F_{\text{v}} &= l \cdot l \cdot B_{\text{h}} \cdot \sin \alpha \cdot 1'200 \\ &\cdot 300 \cdot 10^3 \cdot 40 \cdot 10^{-6} \cdot \frac{V_s}{m^2} \cdot \sin 20^\circ = 2'462.545... \cdot N \end{aligned}$$

For the **overall force** F the Pythagorean theorem has to be used:

$$\begin{aligned} F &= \sqrt{F_{\text{v}}^2 + F_{\text{h}}^2} = \sqrt{(14'400 \cdot N)^2 + (2'462.545... \cdot N)^2} \\ &= 14'609.04... \cdot N \end{aligned}$$

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