

task_elndbo3xwi2klxuu_with_calculation

Student Group

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Exercise E11 Lorentz Force (hard!)

(written test, approx. 10 % of a 120-minute written test, SS2021)

A) The picture below shows a straight high voltage direct current transmission line with a current of $I = 2000 \text{ A}$ flowing into the page. The resulting force is? (Independent)

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 $B_{\text{h}} = 20 \text{ } \mu\text{T}$.

Only a force of 7 N is perpendicular to $\vec{B}_{\text{v}}$ and to $\vec{I}$ and points in the right direction by the right-hand rule.

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 $\vec{F}_{\text{h}}$ of the force is based on the vertical component $\vec{B}_{\text{v}}$ of the magnetic field.
- The vertical component $\vec{B}_{\text{v}}$ of the magnetic field is not shown in the image but is pointing into the ground.
- It has to be perpendicular to $\vec{B}_{\text{v}}$ 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

$$\vec{F}_{\text{L}} = I \cdot \vec{l} \times \vec{B}$$

\end{align*}

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

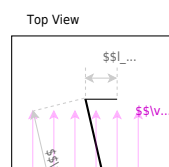
Considering the right-hand rule (and the cross product), the vertical field B_{v} generates a horizontal force F_{h} and vice versa.

The **horizontal component** is given by

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

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.



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

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

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

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