

# Block 16 - Ampère's Law and Magnetomotive Force (MMF)

## Student Group

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# Block 16 - Ampère's Law and Magnetomotive Force (MMF)

## Learning objectives

After this 90-minute block, you can

- ...

## Preparation at Home

Well, again

- read through the present chapter and write down anything you did not understand.
- Also here, there are some clips for more clarification under 'Embedded resources' (check the text above/below, sometimes only part of the clip is interesting).

For checking your understanding please do the following exercises:

- ...

## 90-minute plan

1. Warm-up (x min):
  1. ....
2. Core concepts & derivations (x min):
  1. ...
3. Practice (x min): ...
4. Wrap-up (x min): Summary box; common pitfalls checklist.

## Conceptual overview

1. ...

## Core content

### Generalization of the Magnetic Field Strength

So far, only the rotational symmetric problem on a single wire was considered in formula, when the current  $I$  and the length  $s$  of a magnetic field line around it is given:

$$\begin{aligned} \quad H_{\varphi} &= \frac{I}{s} = \frac{I}{2 \cdot \pi \cdot r} \quad \Leftrightarrow \end{aligned}$$

$\oint \mathbf{H} \cdot d\mathbf{s} = I_{enc}$  applies only to the long, straight conductor

Now, this shall be generalized. For this purpose, we will look back at the electric field.

For the electric field strength  $E$  of a capacitor with two plates at a distance of  $s$  and the potential difference  $U$  holds:

$$U = E \cdot s$$

In words: The potential difference is given by adding up the field strength along the path of a probe from one plate to the other.

This was extended to the voltage between two points  $1$  and  $2$ . Additionally, we know by Kirchhoff's voltage law that the voltage on a closed path is "0".

$$\oint \mathbf{E} \cdot d\mathbf{s} = 0$$

We can now try to look for similarities. Also for the magnetic field, the magnitude of the field strength is summed up along a path to arrive at another field-describing quantity.

Because of the similarity the so-called **magnetic potential difference  $V_m$**  between point  $1$  and  $2$  is introduced:

$$V_m = \int \mathbf{H} \cdot d\mathbf{s}$$

$$V_m = \int \mathbf{H} \cdot d\mathbf{s} = \theta$$

We need to take a closer look here. Any closed path in the static electric field leads to a potential difference of  $\oint \mathbf{E} \cdot d\mathbf{s} = 0$ .

BUT: closed paths in the static magnetic field leads to a magnetic potential difference which is **not mandatorily**  $0$ !  $V_m = \oint \mathbf{H} \cdot d\mathbf{s} = \theta$

Another new quantity is introduced: the **magnetic voltage  $\theta$** :

1. The magnetic voltage  $\theta$  is the magnetic potential difference on a closed path.
2. Since the magnetic voltage  $\theta$  is valid for exactly one turn along our single wire,  $\theta$  is also equal to the current through the wire:  

$$\theta = \oint \mathbf{H} \cdot d\mathbf{s} = I$$
3. The magnetic potential difference can take a fraction or a multiple of one turn and is therefore **not mandatorily** equal to  $I$ .

### Notice:

In general: The path integral of the magnetic field strength along an arbitrary closed path is equal to the free currents (= current density) through the surface enclosed by the path.

The magnetic voltage  $\theta$  (and therefore the current) is the cause of the magnetic field strength.

From the chapter [block15](#) the general representation of the current through a surface is known.

This leads to the **Ampere's Circuital Law**

$$\oint_C \vec{H} \cdot d\vec{s} = \iint_A \vec{S} \cdot d\vec{A} = \theta$$

The magnetic voltage  $\theta$  can be given as

- $\theta = I$  for a single conductor
- $\theta = N \cdot I$  for a coil
- $\theta = \sum_n I_n$  for multiple conductors
- $\theta = \iint_A \vec{S} \cdot d\vec{A}$  for spatial distribution

$d\vec{s}$  and  $d\vec{A}$  build a right-hand system: once the thumb of the right hand is pointing along  $d\vec{A}$ , the fingers of the right hand show the correct direction for  $d\vec{s}$  for positive  $\vec{H}$  and  $\vec{S}$

Fig. 1: Right hand rule



## Common pitfalls

- ...

# Exercises

## Worked examples

...

## Embedded resources

Explanation (video): ...

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