A qualitative approach to the electromagnetic induction fostered by Augmented Reality[1]

Basic idea of the qualitative teaching concept

Field lines are often used to visualize magnetic fields. The number of field lines through a loop of wire is a measure of the magnetic flux. According to Faraday's law the temporal variation of the magnetic flux induces an electromotive force (emf). Hence, for a qualitative understanding of electromagnetic induction phenomena, it is sufficient that students notice that the number of field lines passing through a given area varies. To help students notice temporal variations, Leisen (2010) proposed the "film strip" tool. This is illustrated in Fig. 1 using the example of a Helmholtz coil in which a loop of wire is suspended.

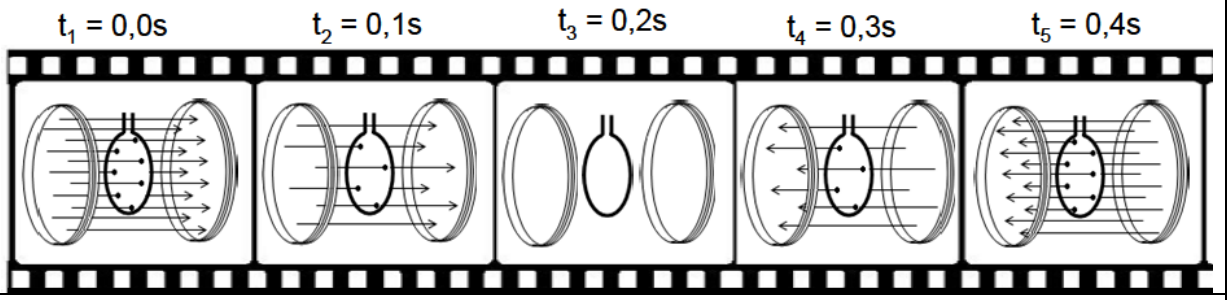

Fig. 1. Usage of the film strip tool to emphasize the role of time in electromagnetic induction. The number of magnetic field lines, which passes through the loop of wire, changes with time.

Visualizing magnetic field lines with Augmented Reality

To promote this basic idea we have developed an application that adopts the Augmented Reality approach. As shown in Fig. 2, a frequency generator provides an alternating voltage (amplitude circa 5 V; period circa 10 s, as displayed on the upper left side of the sinus generator) that generates a current in the Helmholtz coil. The alternating magnetic field of the Helmholtz coil induces an emf (amplitude circa 5 mV) in an induction coil (diameter circa 15 cm; n = 320). In Fig. 2, the QR code attached to the induction coil in the centre of the Helmholtz coil is captured by the tablet's camera to trigger the display of the virtual magnetic field lines. In addition, the tablet continuously measures the magnetic field strength of the Helmholtz coil through its onboard magnetic field sensor. In analogy to Fig. 1, the application superimposes the corresponding number of virtual field lines on the tablet's screen (Fig. 3). Further information about the application is provided in the manual (cf. section "Technical information and download").

[1] This is a shortened version of Berger and Lensing (2021)

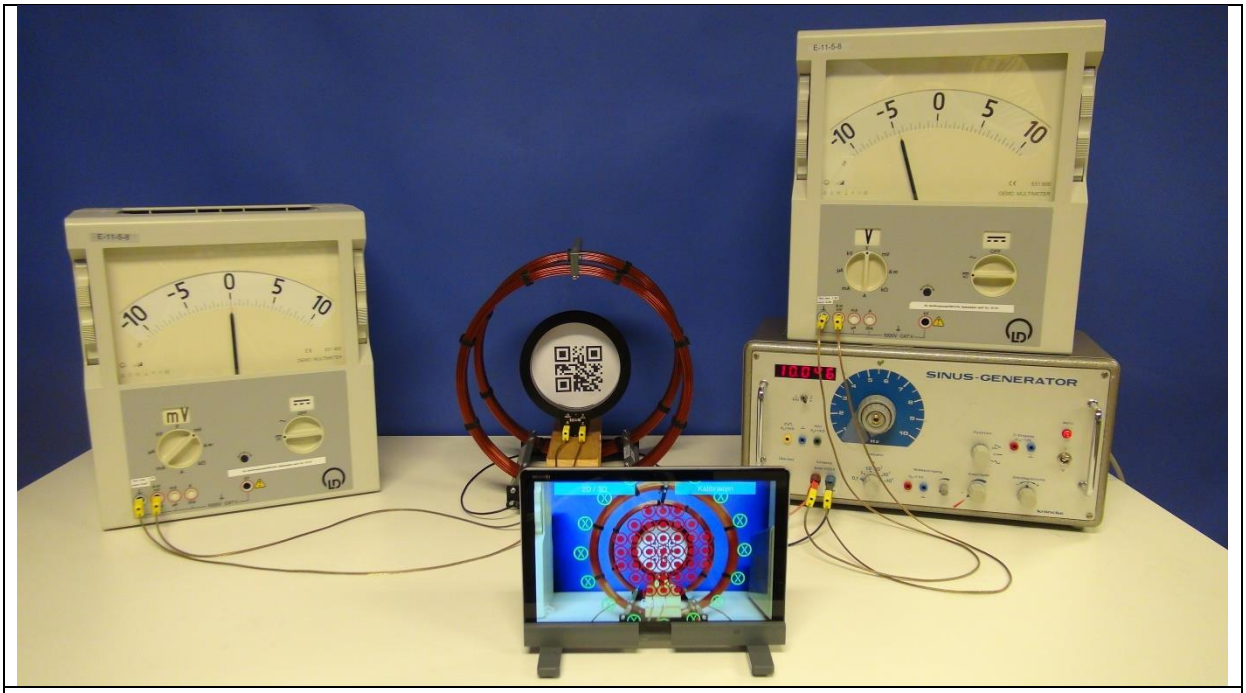

Fig. 2. Experimental setup and Augmented Reality.

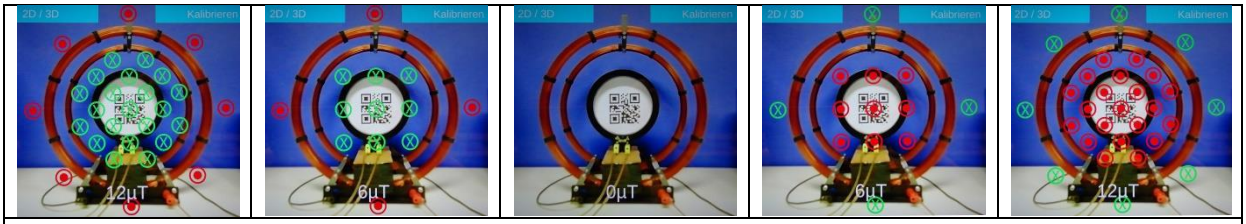

Fig. 3. Temporal development of the magnetic field according to the corresponding film strip in Fig. 1. The green crosses and red dots symbolize magnetic field lines directed into or out of the plane, respectively.

Technical information and download

The application was developed for Android smartphones and tablets. Since the visualization of the magnetic field lines is based on the actual magnetic field strength, the tablet must be equipped with an integrated magnetic field sensor.

The application uses the unity game engine (Unity Technologies, version 2019) as foundation for visualization and Augmented Reality is incorporated using googles ARCore-Engine. Whether a device supports Augmented Reality can be checked online: https://developers.google.com/ar/devices.

Both software engines can be used for free for non-commercial projects. The AR application, the manual and the sources can be downloaded from https://netcase.hs-osnabrueck.de/index.php/s/doR61y9pGTYRwmm

Further reading on the teaching concept

Erfmann and Berger (2015) proposed a teaching concept that adopts this basic idea of counting the number of magnetic field lines from one point in time to another using the film strip tool for various experimental setups.

References

Berger, R. & Lensing, P. (2021). A qualitative approach to the electromagnetic induction fostered by Augmented Reality. Submitted to *The Physics Teacher*.

Erfmann, C. & Berger, R. (2015). Ein elementarer Zugang zur Induktion [An elementary approach to induction]. *Praxis der Naturwissenschaften – Physik in der Schule,* 64*,* 13-25.

Leisen, J. (2010). *Handbuch Sprachförderung im Fach* [Handbook on language skill promotion in subject education]. Varus. (compare also http://www.josefleisen.de/download-methodenwerkzeuge, assessed June 29, 2021)