Magnetic Induction 4.4.02-01/15

Set-up of experiment P2440215 with FG-Module

What you can learn about …

- → Maxwell's equations
- → Electrical eddy field
- → Magnetic field of coils
- → Coil
- → Magnetic flux
- → Induced voltage

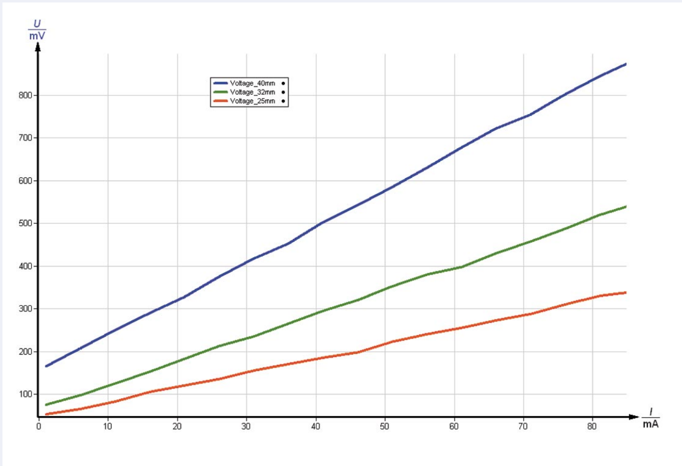
Principle:

A magnetic field of variable frequency and varying strength is produced in a long coil. The voltages induced across thin coils which are pushed into the long coil are determined as a function of frequency, number of turns, diameter and field strength.

What you need:

		Experiment P2440201 with counter	Experiment P2440215 with FG-Module
Function generator	13652.93	1	
Digital counter, 4 decades	13600.93	1	
Digital multimeter	07134.00	2	
Field coil, 750 mm, 485 turns/m	11001.00	1	1
Induction coil, 300 turns, d = 40 mm	11006.01	1	1
Induction coil, 300 turns, d = 32 mm	11006.02	1	1
Induction coil, 300 turns, d = 25 mm	11006.03	1	1
Induction coil, 200 turns, d = 40 mm	11006.04	1	1
Induction coil, 100 turns, d = 40 mm	11006.05	1	1
Induction coil, 150 turns, d = 25 mm	11006.06	1	1
Induction coil, 75 turns, d = 25 mm	11006.07	1	1
Connecting cord, l = 750 mm, red	07362.01	4	2
Connecting cord, l = 750 mm, blue	07362.04	2	1
Connecting cord, l = 2000 mm, blue	07365.04	1	1
Cobra3 Basic Unit	12150.00		1
Power supply, 12 V-	12151.99		2
RS232 data cable	14602.00		1
PowerGraph Software	14525.61		1
Measuring module function generator	12111.00		1
PC, Windows® 95 or higher			

Complete Equipment Set, Manual on CD-ROM included
Magnetic Induction P24402 01/15



Induced voltage as a function of current for different coils.

Tasks:

Determination of the induction voltage as a function

1. of the strength of the magnetic field,
2. of the frequency of the magnetic field,
3. of the number of turns of the induction coil,
4. of the cross-section of the induction coil.

Magnetic induction

Related topics
Maxwell's equations, electrical eddy field, magnetic field of coils, coil, magnetic flux, induced voltage.

Principle
A magnetic field of variable frequency and varying strength is produced in a long coil. The voltages induced across thin coils which are pushed into the long coil are determined as a function of frequency, number of turns, diameter and field strength.

Equipment

Field coil, 750 mm, 485 turns/m	11001.00	1
Induction coil, 300 turns, d = 40 mm	11006.01	1
Induction coil, 300 turns, d = 32 mm	11006.02	1
Induction coil, 300 turns, d = 25 mm	11006.03	1
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Induction coil, 100 turns, d = 40 mm	11006.05	1
Induction coil, 150 turns, d = 25 mm	11006.06	1
Induction coil, 75 turns, d = 25 mm	11006.07	1
Function generator	13652.93	1
Digital counter, 4 decades	13600.93	1
Digital multimeter	07134.00	2
Connecting cord, l = 750 mm, red	07362.01	4
Connecting cord, l = 750 mm, blue	07362.04	2
Connecting cord, l = 2000 mm, blue	07365.04	1

Tasks
Determination of the induction voltage as a function
1. of the strength of the magnetic field,
2. of the frequency of the magnetic field,
3. of the number of turns of the induction coil,
4. of the cross-section of the induction coil.

Set-up and procedure
The experimental set-up is as shown in Fig. 1. The coil current and the induction voltage are measured with the digital multimeters. The effect of frequency should be studied between 1 kHz and 12 kHz, since below 0.5 kHz the coil practically represents a short circuit and above 12 kHz the accuracy of the measuring instruments is not guaranteed.

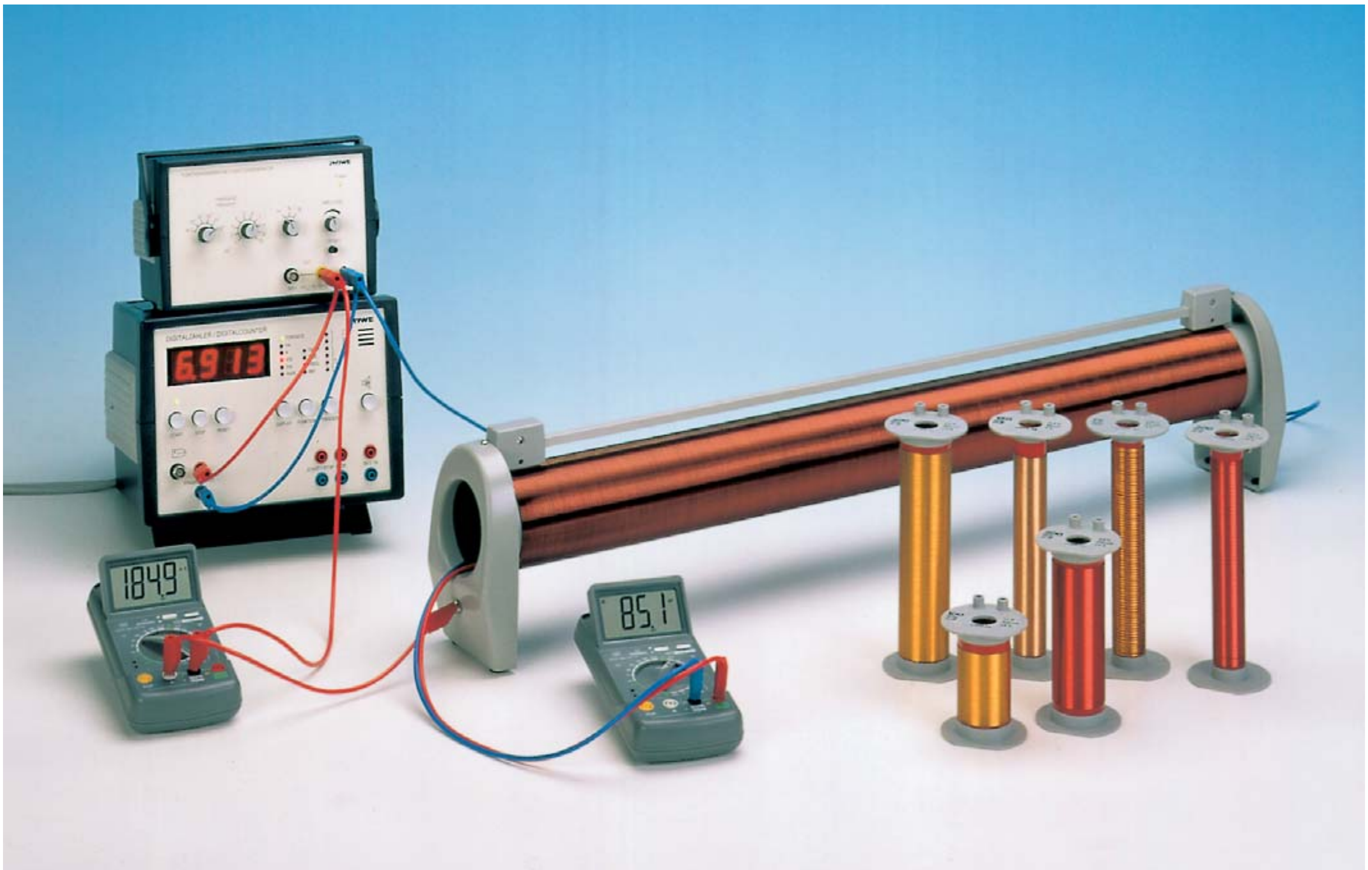
Theory and evaluation
The variation with time of the magnetic flux ϕ, where:

$$\phi = \int_A \vec{B} \cdot d\vec{A}$$

produces an electical voltage U

$$U = \oint_C \vec{E} \cdot d\vec{s}$$

Fig. 1: Experimental set-up for magnetic induction.



Where $\vec{E}$ is the electrical field strength, $\vec{B}$ is the magnetic flux density, A is the area enclosed by the conductor loop and C is its boundary.

The relationship between ϕ and U is given by Maxwell's 2nd equation and is

$$U = -\frac{\mathrm{d}\phi}{\mathrm{d}t}$$

for one conductor loop.

For n parallel conductor loops through which the same flux ϕ passes,

$$U = n \oint \vec{E} \cdot \mathrm{d}\vec{s}$$

In the present case, the magnetic field is produced by a long coil ("primary coil"). Since $\vec{B}$ is constant inside long coils,

$$\phi = \vec{B} \cdot \vec{A}.$$

Maxwell's 1st equation

$$\mu_0 \cdot \oint_{C'} \vec{B} \cdot \mathrm{d}\vec{s} = \int_{A'} \vec{j} \cdot \mathrm{d}\vec{A},$$

together with Maxwell's 4th equation

$$\oint_{A'} \vec{B} \cdot \mathrm{d}\vec{A} = 0$$

gives the relationship between the steady current I flowing the area A'

$$I = \int_{A'} \vec{j} \cdot \mathrm{d}\vec{A}$$

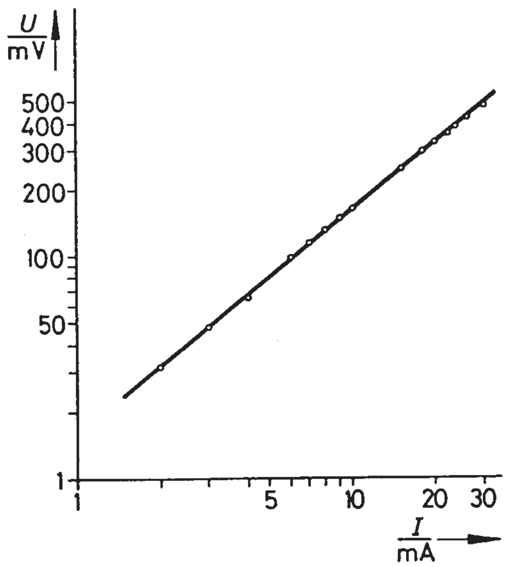
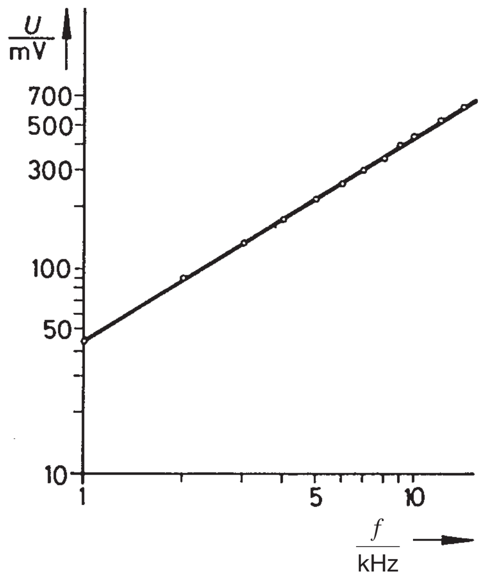


Fig. 2: Induced voltage as a function of the current in the primary coil at f = 10.7 kHz, diameter of the induction coil d = 41 mm.

Fig. 3: Induced voltage as a function of the frequency in the primary coil with a primary current of 30 mA and an induction coil diameter of 41 mm.



and the magnetic field $\vec{B}$ produced thereby. C is the boundary of A, A" is any desired enclosed area, $\vec{j}$ the electrical current density and μ_o the magnetic field constant:

$$\mu_o = 1.26 \cdot 10^{-6} \frac{\mathrm{Vs}}{\mathrm{Am}}.$$

For a long coil with n' turns, one obtains

$$|\vec{B}| = \mu_o n' \cdot I/l$$

inside the coil.

If an alternating current I of frequency f or angular frequency f or angular frequency ω flows through the primary coil,

$$I = I_o \cdot \sin \omega t,$$

then, from (1), the voltage induced in a secondary coil (n turns, crosssectional area A) is obtained:

$$U = -\mu_o nA \cdot n'\omega I_o/l \cdot \cos \omega t$$

The results of the different experiments are shown in Fig. 2–5 and listed in Table 1.

Table 1

Fig.	Exponent	Standard Error
2	0.995	±0.023
3	0.996	±0.005
4	1.033	±0.011
5	1.98	±0.023

Fig. 4: Induced voltage as a function of the diameter of the secondary coil with a primary current of 30 mA and a frequency of 10.7 kHz.

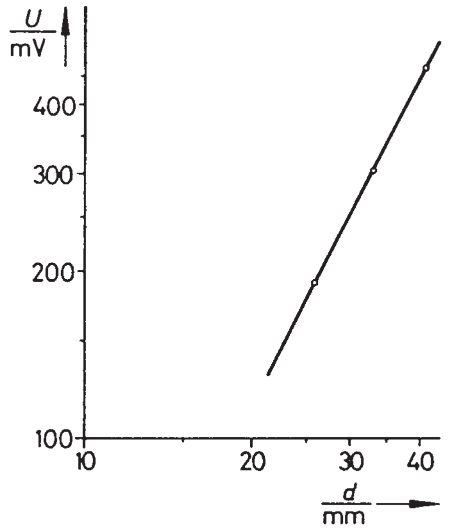


Fig. 5: Induced voltage as a function of the number of turns of the secondary coil with a primary current of 30 mA and a frequency of 10.7 kHz.