Rotating frame with flat coil 1013131

Instruction sheet

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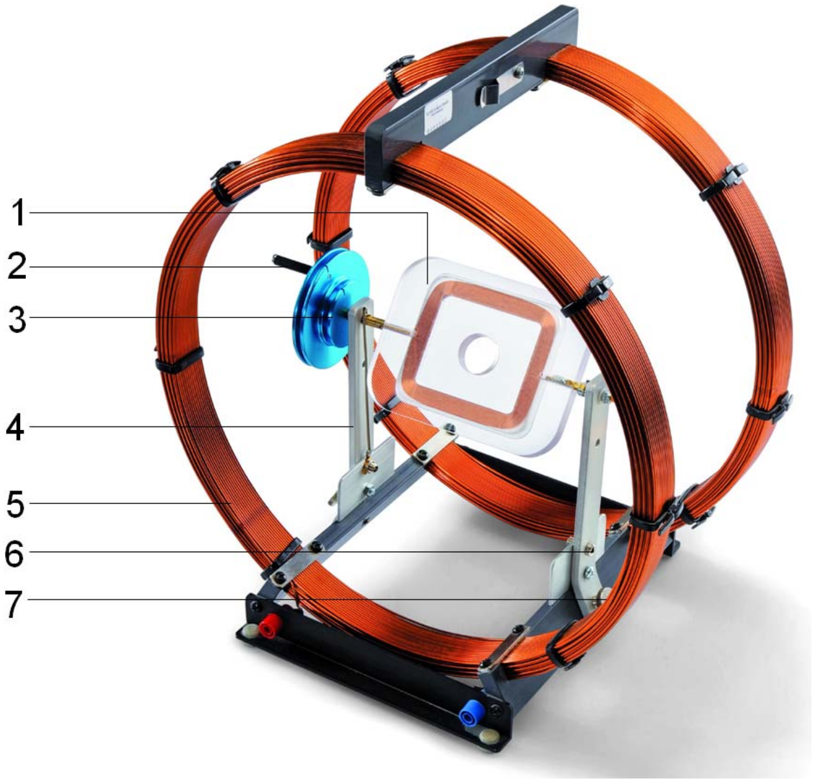

1 Flat coil
2 Hand crank
3 Pulley
4 Supports
5 Helmholtz coils (not included)
6 4-mm output socket
7 Knurled screw for securing support

1. Description

The rotating frame with flat coil is for conducting various experiments on the subject of “electro-magnetic induction” in conjunction with the pair of Helmholtz coils (1000906).

The flat coil in located in a rotating Plexiglass frame. Electrical connection to the coil is made via sliding brush contacts. A pulley and a hand crank on the axis of the rotating frame can be used to turn the coil. The supports of the rotating frame are secured by means of knurled screws to the crossbar between the Helmholtz coils.

2. Technical data

Number of turns:	4,000
Effective surface:	41.7 cm^2
Coil mount:	Plexiglass
Dimensions:	110 x 80 x 11 mm^3
Length of supports:	160 mm approx.
Electrical connection	Via brushes
Weight:	360 g approx.

3. Theoretical bases

The flat coil is rotated in an external magnetic field so that the induced voltage can be measured at the coil ends.

In order to accurately measure the induced voltage, it is necessary to know the variables, on which the induced voltage depends. These are the strength of the external magnetic field, the speed with which it crosses the magnetic field lines and the charge on the charged particles that are passing through the magnetic field. These 3 variables are related to each other by the expression for the so-called “Lorentz force”:

$$\vec{F} = q \cdot \vec{v} \times \vec{B}$$

This force acts in a direction perpendicular to both the field B and the direction of movement of the charged particles.

Due to the shape of the coil and the characteristics of the medium in which the charged particles move, an induced voltage arises at the end of the copper loop, the magnitude of which is multiplied by the number of turns in the coil so that it can be measured with a normal meter.

In order to create a uniform motion, the rotating coil is connected to a slowly rotating motor. A magnetic field that is uniform in strength and direction over a large volume is space is created external to the coil by the Helmholtz coil set-up.

The charge carriers are the free electrons that move within the copper coil. Their charge is also constant.

The rotation of the coil in the field generates a sinusoidal alternating voltage:

$U = U_m \cdot \sin \omega t$ where $U_m = n \cdot A \cdot B \cdot \omega$ and $\omega = 2 \cdot \pi \cdot f$

n = Number of turns in the coil

B = Magnetic flux

A = Surface area of coil

f = Frequency of rotation of the coil within the field

A and n can be determined directly. B can be determined indirectly from the Helmholtz arrangement. The coil's frequency of rotation f can be adjusted by changing the speed of the motor and can be measured using a photocell light barrier.

The induced voltage can be determined using an oscilloscope or a voltmeter with its zero point calibrated in the centre of the dial.

For very slow rotations of the flat coil, a measurement amplifier may be necessary.

4. Operation

- Screw the supports of the rotating frame with the flat coil to the crossbar of the Helmholtz coils, so that the flat coil can rotate in the middle of the uniform field produced by the Helmholtz coils.
- First, conduct a preliminary experiment, turning the coil by hand in order to estimate the level of the induced voltage.
- Then make a loop of string to connect the pulley to the motor.
- Conduct the subsequent experiments using this arrangement.

5. Sample experiments

In order to perform the experiments,the following equipment is also required:

1 DC power supply 20 V, 5 A (230 V, 50/60 Hz) 1003312

or

1 DC power supply 20 V, 5 A (115 V, 50/60 Hz) 1003311

2 Multimeter Escola 10 1006810

1 Pair of Helmholtz coils 1000906

5.1 Voltage induction in a magnetic field

- Position the Helmholtz coils on the table top and connect them in series to the DC power supply via an ammeter.
- Screw the supports of the rotating frame with the flat coil to the crossbar of the Helmholtz coils, so that the flat coil can rotate in the middle of the uniform field produced by the Helmholtz coils.
- Connect a voltmeter with a central zero point directly across the coil.
- Set the power supply current for the coils to about 1.5 A.
- Use the hand crank and observe the deflection of the voltmeter.
- Change the speed of rotation so that a larger deflection is obtained. The rotation speed needs to be low.

In order to achieve a constant speed of rotation, use of a slowly rotating motor (e.g. 12 V DC motor 1001041) is recommended for driving the rotating frame.

A precise voltage trace can also be observed and measured using an oscilloscope.

5.2. Determination of the earth's magnetic field from the induction voltage

Using the same experiment set-up, it is also possible to measure the earth's magnetic field.

- Align the Helmholtz coils in such a way that the magnetic field of the coils is parallel to the Earth's field.
- Rotate the flat coil and observe the voltage.
- Increase current to the Helmholtz coils until the voltage induced at the outputs of the flat coil is zero (so that the earth's magnetic field and the field of the Helmholtz coils cancel out).
- When the induced current is 0, then the magnetic field in the coils is of the same magnitude as the Earth's magnetic field.

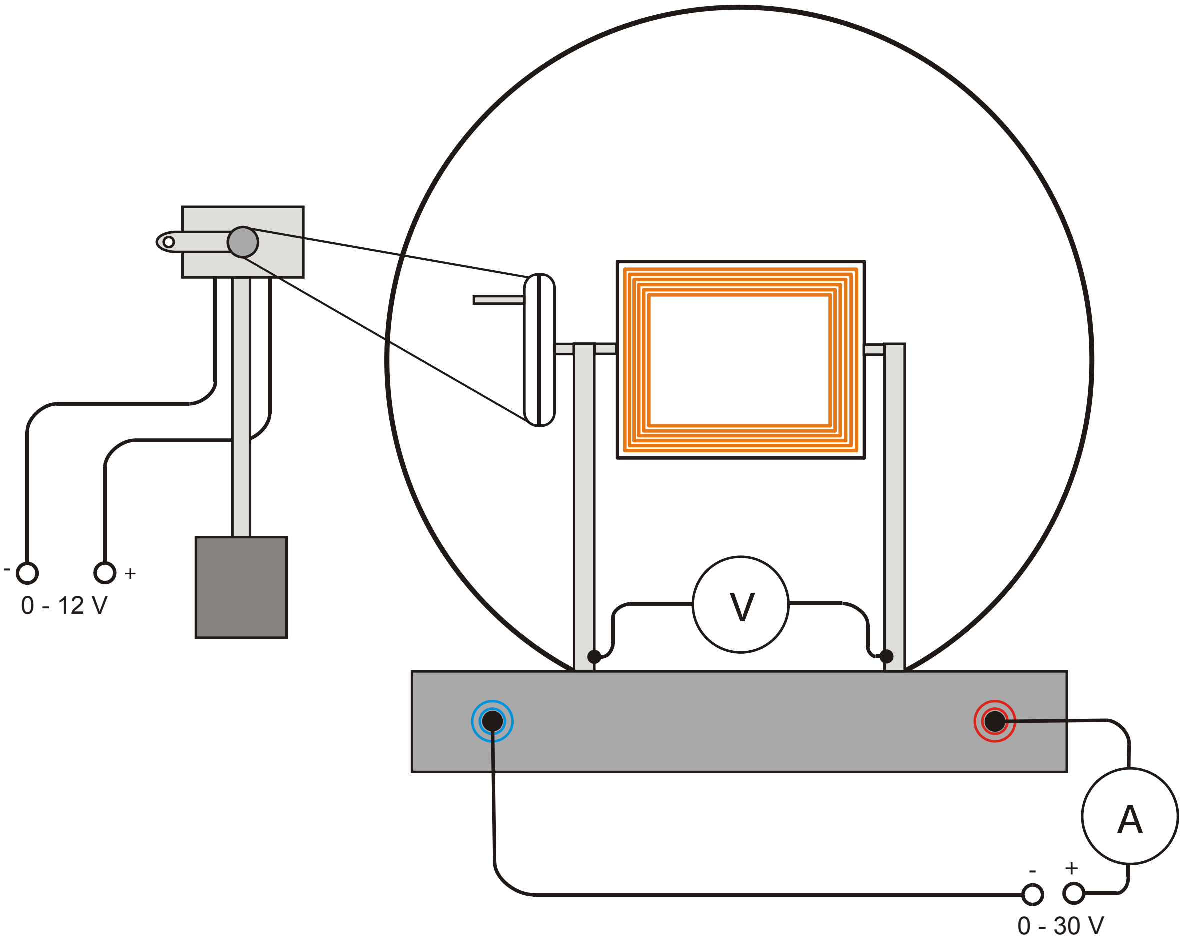

Fig. 1 Experiment set-up with flat coil and driving motor