LEYBOLD-HERAEUS

4/75 Instruction sheet Cat. No. 516 40

Induction apparatus with conducting loop

The induction law refers to one of the essential relations between electrical phenomena and magnetic field. Its detailed experimental treatment, therefore, yields fundamental concepts for wide fields of electricity, magnetism and atomic physics.

The induction apparatus (fig. 1) allows an exact and comprehensive demonstration of the induction law and of the definition following thereof, of the magnetic flux Φ and the magnetic flux density *B*. Therefore, it represents a basic teaching apparatus for physics lessons which can be used for demonstration purposes as well as for practical work.

1. Technical data

1.1. Dimensions of the conducting loops
- (1) 500 mm x 40 mm (rectangular)
- (2) 500 mm x 20 mm (rectangular)
- (3) 500 mm x 28.3 mm = 500 mm x 40 mm cos 45^{o} (trapezoidal)

1.2. Magnetic induction between the pole pieces with 16 magnets: approx. 5×10^{-2} T

1.3. Distance of the pole pieces: 8 mm

1.4. Diameter of the shaft of the slip friction clutch:

d_1 = 8 mm
d_2 = 16 mm
d_3 = 32 mm

1.5. Dimensions of the induction apparatus:
- a) folded 140 mm x 500 mm x 80 mm
- b) ready to operate: 140 mm x 1000 mm x 80 mm

1.6. Weight: 8,5 kg

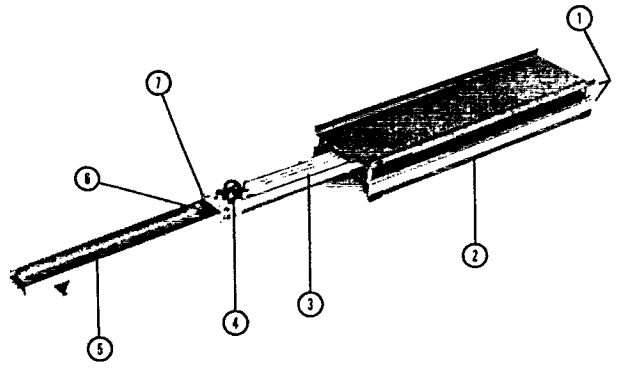


Fig. 1 Induction apparatus

2. Description

The standard specification of the apparatus includes:

1 induction apparatus with carriage
4 cylindrical magnets
1 slip friction clutch

The induction apparatus (fig. 1) consists of:

① two parallel plates (iron) which are mounted firmly at a clearance of approx. 20 mm one above the other.

Over the whole length between the plates pole pieces made of magnetically well conducting material are mounted. The gap between the pole pieces is 8 mm. Cylindrical magnets, cat. no. 510 48, can be inserted in a lateral

position to the pole pieces into the induction apparatus. Therefore, a relatively homogeneous magnetic field is produced between the pole pieces. Its strength depends on the number of the inserted magnets. No less than 4 cylindrical magnets are necessary; the maximum of the inserted magnets is 16 pieces.

When inserting the magnets attention must be paid to correct polarity — all poles marked in red must point in the same direction — and to correct positioning of the magnets.

② Markings for the position of the magnets.
When inserting n magnets (n = 4, 8, 12, 16) always a magnet has to be inserted at the place marked with n_1.

③ Carriage running between the pole pieces. On the top of the carriage three conducting loops are attached in the middle between the pole pieces.

④ Shorting plug for connecting the sockets at the ends of the conducting loops. The connection is made by means of a tightly coupled screened cable which in its turn can be connected to the voltage sensitive amplifier, cat. no. 532 06 in combination with the matching measuring instrument, e.g. demonstration multirange meter, cat. no. 531 86 or 87, or twin moving-coil instrument, cat. no. 442 76 or 442 86.

⑤ Unfolding rail for guiding the carriage in extension of the induction apparatus. Within the induction apparatus the carriage is guided by the pole pieces themselves. In this way at each phase rectilinear motion of the carriage is ensured (and thus also rectilinear motion of the conducting loops). At the end of the rail there is a stop so that the carriage can not be extracted farther out of the induction apparatus.

At the front end of the carriage a fishing line of approx. 0.5 m in length is attached. It is laid through the sloping groove provided in the stop of the guiding rail and is knotted in the slit of the slip friction clutch. The slip friction clutch is inserted into the chuck of the standard electric motor, cat. no. 347 25.

On altering the rotational speed of the motor (by means of control unit, cat. no. 347 33 or adapter, cat. no. 347 32, and rheostat 320 Ω, cat. no. 537 23) the desired speed for the carriage can be adjusted.

The shaft of the slip friction clutch is stepped. In this carriage speeds in the ratio 1:2:4 can be produced, if at constant rotational speed of the motor the fishing line is successively wound up on the different steps.

As often as the carriage runs against the stop of the guiding rail the clutch is slipping. This prevents tearing of the fishing line or overthrowing of the assembly.

The front end of the carriage is provided with a microswitch.

⑥ In front of this microswitch a sheet-metal strip is mounted in vertical position for actuating the microswitch. It separates then the connected measuring instrument (amplifier) from the conducting loops. Therefore, the sliding back of the carriage into its initial position should only be made by means of the sheet strip as, to the normally quick motion of the carriage through the magnetic field would cause too great a negative deflection on the meter.

⑦ Crossbar at the front end of the carriage for actuating the contact plates when the carriage is living the magnetic field (see experiments). In this crossbar a 4-mm socket is inserted. When a 4-mm plug is plugged into the socket and a strip of paper attached to it, the stop-clock can be actuated by means of light barriers instead of contact plates.

3. Functioning

On moving the conducting loops across the magnetic field between the pole pieces of the induction apparatus a voltage U_{ind} will be produced at the ends of the conducting loops corresponding to

$$U_{ind} = -\frac{d\Phi}{dt} = \frac{d\,(BA)}{dt}$$

Φ is the magnetic flux determined by the number of the inserted magnets and is equal on the other hand to the product of the magnetic flux density B and the area A.

On moving the conducting loops out of the field of the pole pieces, a variation with time of the magnetic flux permeating the conducting loops will be attained. If the variation occurs with constant speed a constant induction U_{ind} will be produced.

4. Use

4.1. Assembly

a) unfold the rail ⊙

b) insert the cylindrical magnets or additional cylindrical magnets, cat. no. 570 48

c) assemble the standard electric motor, cat. no. 347 25/26 on front of the rail (e.g. by means of a bench clamp at the brim of the table)

d) insert the slip friction clutch into the chuck of the standard electric motor

e) insert the fishing line attached to the carriage into the cross groove of the stop and into the slit of the slip friction clutch (make sure that the fishing line is straight and in horizontal position)

f) connect the screened cable of the voltage sensitive amplifier (cat. no. 532 06)

g) connect the conducting loop by inserting the U-link

4.2. Apparatus required

For experimenting with the induction apparatus the following equipment is necessary:

a) standard electric motor (cat. no. 347 25/26) in combination with the control unit (cat. no. 347 33) or adapter for the standard electric motor (cat. no. 347 32)
(required in addition: rheostat 320 Ω cat. no. 537 23 at 220 V or 110 Ω at 110 V cat. no. 537 24)

b) 12 cylindrical magnets (cat. no. 570 48)

c) voltage sensitive measuring amplifier (cat. no. 532 06) in combination with measuring instrument, e.g. demonstration multirange meter (cat. no. 531 86) or demonstration millivolt-microammeter (cat. no. 531 87) or twin moving-coil instrument (cat. no. 442 76/86) in combination with range control box (cat. no. 442 74/84)

d) stop-watch (cat. no. 313 06/07) or stop-clock (cat. no. 313 05) or two small contact plates (cat. no. 336 24) and the large electric stop-clock (cat. no. 313 04/02/08)

4.3. Useful notes for experimentation

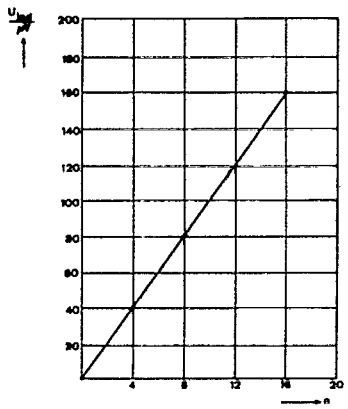
4.3.1. The field between the pole pieces is proportional within the limits accuracy to the number of magnets (see fig. 2). The absolute value depends on the strength of the magnets used, on the magnetic shunt between the magnets and the iron, and on the iron and the pole-piece material used. When using 16 magnets it is of the order of 5×10^{-2} T. The earth's magnetic field of order of 5×10^{-5} T can be neglected in comparison.

4.3.2. Care has to be taken that the windings of the fishing line do not overlap as otherwise the speed of the carriage will not be constant. Therefore, it will be preferable to mount the motor in such a way that the fishing line, before it is pulled out, is in the straightest possible (and horizontal) position between the front end of the carriage through the stop up to the slip friction clutch.

4.3.3. At a speed of the carriage of approx. 5 cm/s (i.e. when using the smallest shaft of the slip friction clutch at approx 100 r.p.m. of the motor shaft) values for U_{ind} will result within the order of magnitude of 100 μV, in case that 16 magnets were used.

Examples of experiments

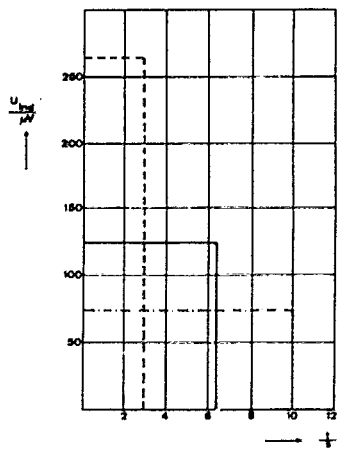
1) Induced voltage as a function of the number of the magnets used



Insert one after the other 4, 8, 12, 16 magnets into the induction apparatus and pull the carriage at constant speed out of the apparatus. U_{ind} will then be proportional to the magnetic induction existing between the pole pieces (fig. 2).

Fig. 2

2) Induced voltage as a function of the speed of the conducting loop



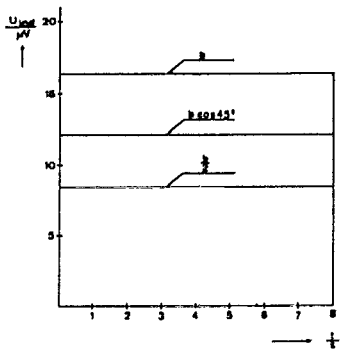
At constant number of the inserted cylindrical magnets the speed is varied with which the carriage is pulled out of the induction apparatus. It results

$$\int_{t_1}^{t_2} U\,dt = \text{const}$$

(see fig. 3).

Fig. 3

3. Induced voltage in function of width of the conducting loop



At constant number of inserted magnets and at constant speed of the conducting loop the induced voltage will be measured at the ends of the different conducting loops one after the other. It will result proportionality between U_{ind} and the width b and, therefore, proportionality to the area A inclosed by the conducting loop (see fig. 4).

Fig. 4

LEYBOLD-HERAEUS GMBH & CO · KG · 5000 KÖLN 51
BONNER STRASSE 504 · ⊡ 510760 · ☎ KÖLN [0221] 37011 · 8 88 28 15 leyd · LEYBOLDHERAEUS KÖLN

0,2-4-76/2. Ed. Cr.
Printed in F. R. G.