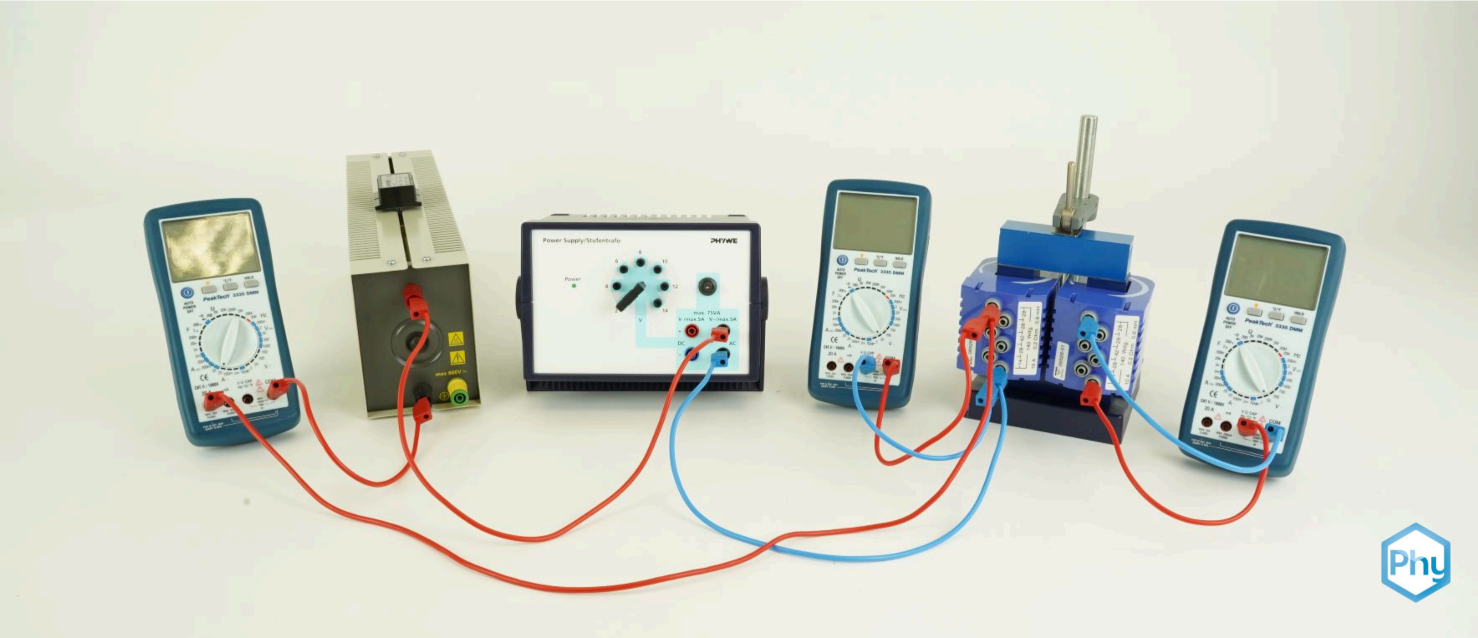
Transformer



Physics | Electricity & Magnetism | Electromagnetism & Induction

Difficulty level	Group size	Preparation time	Execution time
-	-	-	-

This content can also be found online at:

http://localhost:1337/c/6014561538ab09000357da60

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

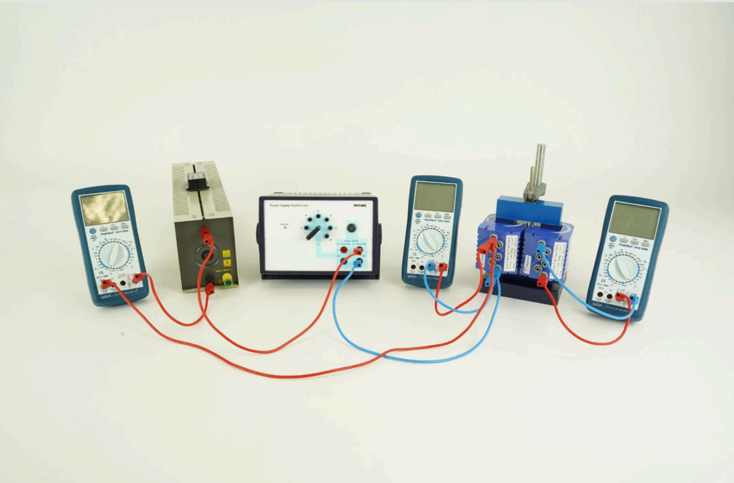
info@phywe.de
www.phywe.de

PHYWE

General information

Application

PHYWE



Experimental Setup

A transformer is a component that transfers electrical energy from one electrical circuit to one or multiple other circuits. A varying current in one of the transformers coils producesa varying magnetic flux in the core of the transformer which leads to an induction of a varying electromotive force across any other coils which are wound around the same core.

Transformers are mostly used for increasing low AC voltages at high current or decreasing high AC voltages at low current in electric power applications.

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Other information (1/2)

PHYWE

Prior knowledge

The prior knowledge required for this experiment is found in the theory section.

Scientific principle

An alternating voltage is applied to one of two coils (primary coil) which are located on a common iron core. The voltage induced in the second coil (secondary coil) and the current flowing in it are investigated as functions of the number of turns in the coils and of the current flowing in the primary coil.

Other information (2/2)

PHYWE

Learning objective

The goal of this experiment is to investigate the behaviour of a transformer. The students should develop an understanding of the terms induction and magnetic flux.

Tasks

1. Determination of the secondary voltage on the open circuited transformer.
2. Determination of the short-circuit current on the secondary side
3. Determination of the primary current while the transformer is loaded.

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Theory

PHYWE

If a current I flows in a coil because of the alternating voltage applied, then according to Maxwell's 2nd equation the induced voltage in the coil is $U_{\text{ind}} = -n_1 \frac{d\Phi}{dt}$ (1)

where n_1 is the number of turns in the coil and Φ is the magnetic flux density. This voltage is opposite in polarity to U_1 and therefore

$U_1 = n_1 \frac{d\Phi}{dt}$ (2)

If there is a second coil (secondary coil) on the same iron core, so that the same flux density Φ passes through the secondary coil, then the induced voltage U_1 is

$U_2 = \frac{n_2}{n_1} U_1$ (3)

or, from (2) $U_2 = -n_2 \frac{d\Phi}{dt}$ (4)

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Equipment

Position	Material	Item No.	Quantity
1	PHYWE Multitap transformer DC: 2/4/6/8/10/12 V, 5 A / AC: 2/4/6/8/10/12/14 V, 5 A	13533-93	1
2	Rheostat, 10 Ohm , 5.7A	06110-02	1
3	Coil, 140 turns, 6 tappings	06526-01	2
4	Clamping device for iron cores	06506-00	1
5	Iron core, U-shaped, laminated	06501-00	1
6	Iron core, I-shaped, laminated	06500-00	1
7	Digital multimeter, 600V AC/DC, 10A AC/DC, 20 MΩ, 200 µF, 20 kHz, −20°C… 760°C	07122-00	3
8	Connecting cord, 32 A, 500 mm, red	07361-01	1
9	Connecting cord, 32 A, 500 mm, blue	07361-04	1
10	Connecting cord, 32 A, 250 mm, red	07360-01	3
11	Connecting cord, 32 A, 250 mm, blue	07360-04	3

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Setup and Procedure

Setup

- The experimental set-up is as shown in Fig. 1.
- The iron yoke should be opened only when the supply is switched off, as otherwise excessive currents would flow.
- When loading the rheostat, the maximum permissible load of 6.2 A for 8 minutes must not be exceeded.
- The power unit is non-grounded, so that the phase relationship of current and voltage can be displayed with a dual-channel oscilloscope.

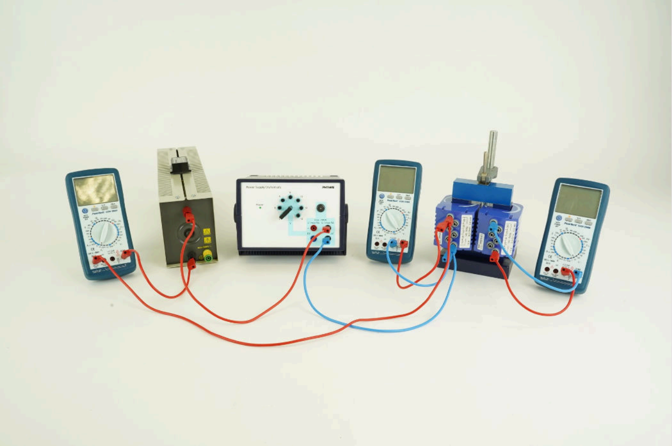


Fig.1: Experimental set-up

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Procedure

PHYWE

- At constant supply voltage, the primary current is adjusted using the rheostat in the primary circuit, with the secondary short-circuited. When the transformer is loaded, the rheostat is used as the load resistor in the secondary circuit.
- The secondary voltage on the open circuited transformer is determined as a function of the number of turns in the primary coil, of the number of turns in the secondary coil and of the primary voltage.
- The short-circuit current on the secondary side is determined as a function of the number of turns in the primary coil, of the number of turns in the secondary coil and of the primary current.
- With the transformer loaded, the primary current is determined as a function, of the secondary current, of the number of turns in the secondary coil and of the number of turns in the primary coil.

PHYWE

Evaluation

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Results (1/5)

PHYWE

From the regression line to the measured values of Fig. 2 and the exponential statement

$Y = A \cdot X^B$

there follows the exponent $B = 1.020 \pm 0.002$

From the regression line to the measured values of Fig. 4 and the exponential statement

$Y = A \cdot X^B$

$B_1 = 1.002 \pm 0.001; B_2 = -0.993 \pm 0.002$

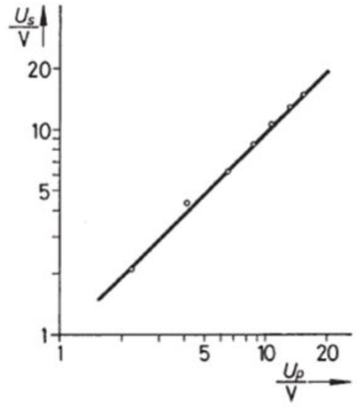


Fig. 2: Secondary voltage on the unloaded transformer, as a function of the primary voltage.

Results (2/5)

PHYWE

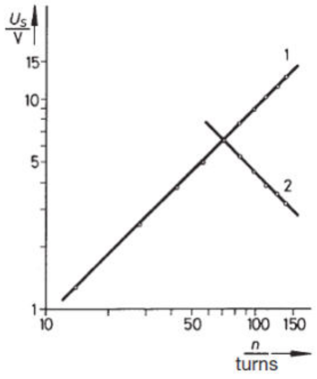


Fig. 3: Secondary voltage of the unloaded transformer as a function 1. of the number of turns in the secondary coil, 2. of the number of turns in the primary coil.

If a current I_2 flows in the secondary circuit, the resultant magnetic flux is superimposed on the flux density in the primary coil: the a.c. impendance of the primary coil decreases as a result. Therefore the current in the primary coil increases with constant supply voltage U.

Since the flux produced by I_2 in the secondary coil is equal to the flux produced by the additional current I_1 in the primary coil, it follows that

$I_2 = -\frac{n_1}{n_2} I_1$ (5)

The quotient n_1/n_2 is called the transformation ratio.

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Results (3/5)

PHYWE

If the load on the secondary side is purely resistive and if the current flowing in the primary when the transformer is unloaded is small in comparison with I_1,then I_1 is the total current flowing on the primary side.

From the regression line to the measured values of Fig. 4 and the exponential statement

$Y = A \cdot X^B$

there follows the exponent $B = 1.02 \pm 0.01$

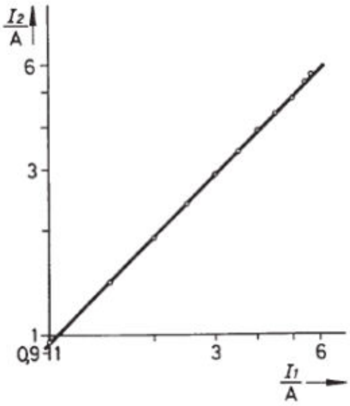


Fig. 4: Secondary short-circuit current as a function of the primary current in the transformer.

Results (4/5)

PHYWE

From the regression line to the measured values of Fig. 5 and the exponential statement

$Y = A \cdot X^B$

there follows the exponents

$B_1 = -0.982 \pm 0.003 B_2 = 1.025 \pm 0.002$

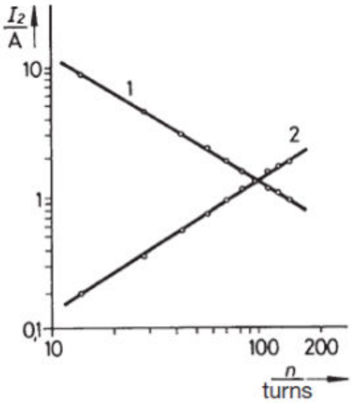


Fig. 5: Secondary short-circuit current of the transformer as a function (1). of the number of turns in the secondary coil, (2). of the number of turns in the primary coil.

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Results (5/5)

The losses of a transformer are mainly given by the ohmic resistance of the coil, the magnetisation and hysteresis losses of the iron core, and losses through stray fields arising because the total primary magnetic flux does not pass through the secondary coil, and vice versa. The inductive reactances and ohmic resistances of the primary and secondary circuits vary because of this.

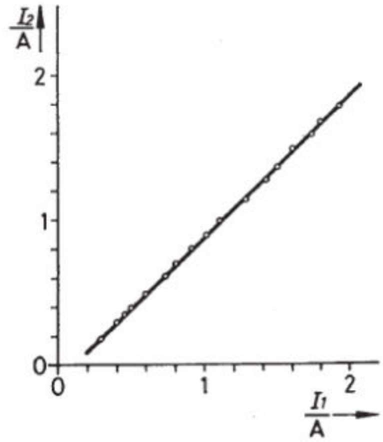


Fig 6: Secondary current as a function of the primary current, with the transformer loaded.

Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de