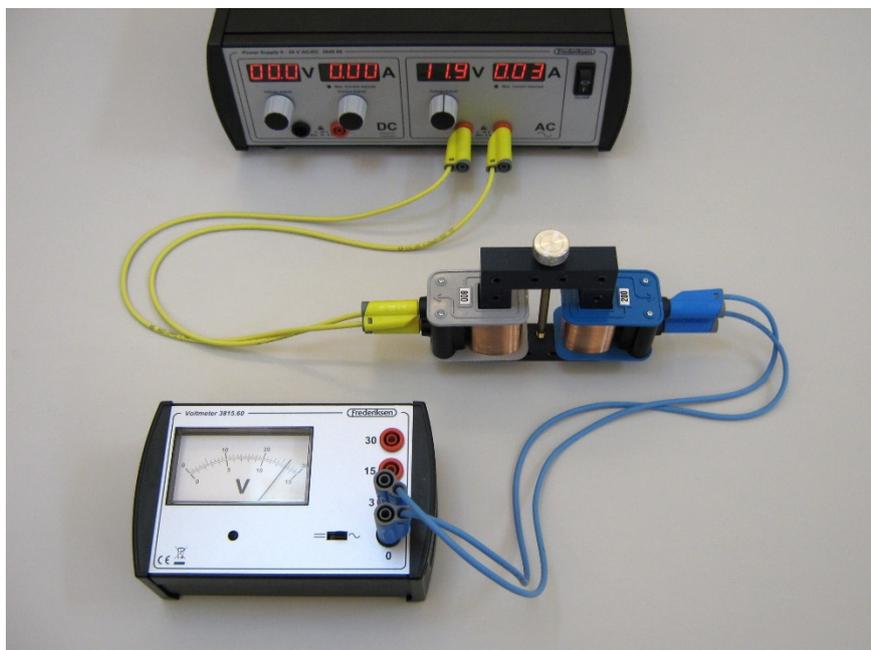


Number	137710-EN	Topic	Magnetism and induction		
Version	2016-04-25 / HS	Type	Student exercise	Suggested for	Grade 9-10
				p.	1/4



## Objective

We will examine a transformer built from individual coils and a UI core.

The results are compared to the theory for the ideal transformer.

## Principle

With the interchangeable coils, the transformer is easy to build with many different winding combinations.

The primary voltage is measured on the built-in voltmeter in the power supply. \*)

The secondary voltage is measured by an external voltmeter.

## Equipment

(Detailed equipment list on last page)

- 463000 UI core
- 462510 Coil f. student transformer, 200 turns
- 462520 Coil, 400 turns (2 are used)
- 462525 Coil, 800 turns
- 381560 Voltmeter
- Power supply \*)
- Lab leads

\*) If you use a power supply without a voltmeter, the primary voltage must be measured with an external voltmeter. This can eventually be the same as used for the secondary voltage – it must then be moved for each measurement.

## Alternative meters

### Multimeters

Instead of Frederiksen's analog instruments, digital multimeters can be used.

With an auto-ranging multimeter, you don't have to change measuring range.

If your multimeter doesn't have auto-ranging, start with a range that covers 30 V. If the actual voltage is small enough to fit the next smaller range, change to that.

If the meter has both "mV" and "V" sockets, use "V" together with the "Com" socket.

### Only one voltmeter for both voltages

Avoid braking the current path at the primary side when the voltmeter is moved.

Follow the instructions [in brackets] on the next page.

## Procedure

Use alternating current – **AC** – on the power supply.  
The voltmeters must also be set for AC.

Before you start – and *every time* you change the circuit – turn down the power supply to 0 V.

**Only** turn up from 0 V when the coils are mounted on the core, the core is assembled, and the screw is tightened.



[ If you use *one* external voltmeter which must be moved between the primary and the secondary side – *do not* turn down in the middle of a measurement. Use two extra cables; move the voltmeter between them. *Do* turn down when changing coils. ]

The transformer consists of two coils and a core. The core can be disassembled in order to change the coils. When reassembling the core, tighten the screw securely.

One coil is connected to an AC voltage – it is called the *primary coil*. The number of windings on the primary coil is called  $N_p$ . The voltage over the primary coil is called the *primary voltage*  $U_p$ .

The other coil is called the *secondary coil*. It has  $N_s$  windings. The secondary coils gives off a voltage – the *secondary voltage*  $U_s$  – which typically is different from  $U_p$ .

**1)** First, use this combination:

$$N_p = 200 ; N_s = 400$$

Build the circuit shown in the photo.

In the first three measurements, the primary voltage must be **approx. 6 V**. Don't waste time trying to hit 6 V exactly, but measure the actual voltage precisely and write it down. A table like the one on the next page can be used for the results.

Measure the secondary voltage and write it down.

Measure the two voltages for these combinations also:

$$N_p = 200 ; N_s = 800$$

$$N_p = 400 ; N_s = 800$$

**2)** For the next three measurements, the primary voltage must be **approx. 12 V**.

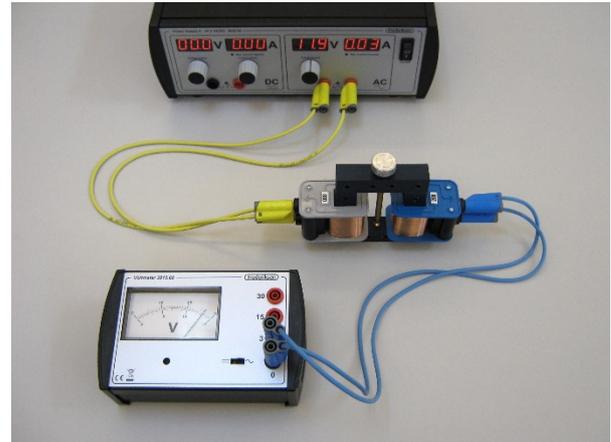
Measure  $U_p$  and  $U_s$  precisely for these combinations:

$$N_p = 400 ; N_s = 400$$

$$N_p = 800 ; N_s = 400$$

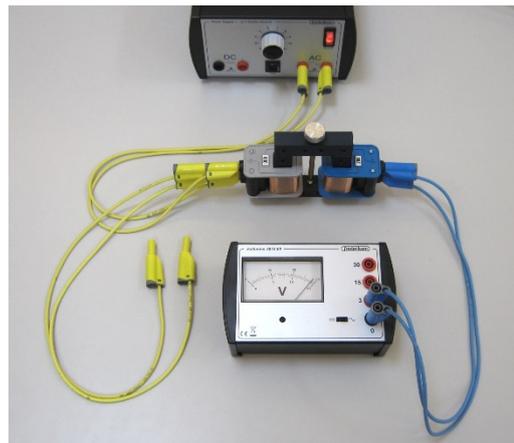
$$N_p = 800 ; N_s = 200$$

### Normal setup



Power supply with a built-in voltmeter for measuring the primary voltage, and an external meter for the secondary voltage.

### Alternative setup (see text)



If you *don't* have a voltmeter in the power supply and only *one* external voltmeter. Use cables with different colours for the voltmeter.

### Theory

From other experiments (with a bar magnet and a coil) you know that a changing magnetic field induces a voltage in a coil.

In the transformer, the primary coil acts like an electromagnet with a constantly varying field caused by the alternating current in the coil.

For an *ideal* transformer, the ratio between the primary and secondary voltages will be the same as the ratio between the number of windings:

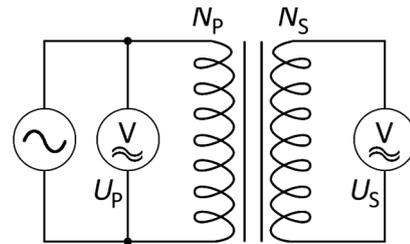
$$\frac{U_S}{U_P} = \frac{N_S}{N_P}$$

(which can be written:  $U_S = \frac{N_S}{N_P} \cdot U_P$ )

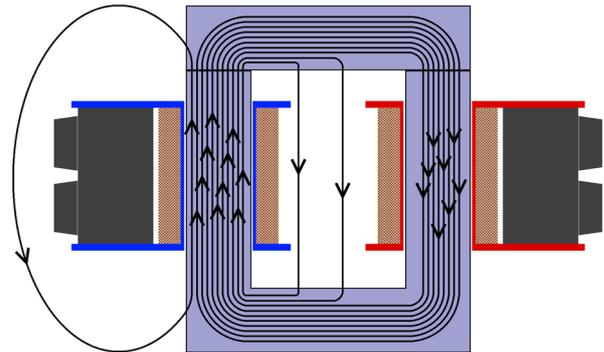
If the voltage is to be transformed *up*, the secondary coil must have *more* windings than the primary. To transform the voltage *down*, the secondary coil must have *less* windings than the primary.

For the transformer to be ideal, all the field lines from the primary coil must go through the secondary coil as well. The iron core is responsible for directing the magnetic field from one coil to the other.

No transformer is 100 % ideal. Most of the field lines go through both coils, but some of them find a way around the secondary coil (see figure). Therefore, the secondary voltage will be some percent lower than given by the formula above.



Schematics for the setup. The power supply is drawn as an AC generator.



Cross section of the transformer

The primary coil is blue, the secondary coil is red. Field lines are drawn also. A "snapshot" is shown – the field changes strength and direction in step with the alternating current.

### Calculations

Present the results in a table like this:

$N_P$	$N_S$	$U_P$	$U_S$	$U_{S,theory}$	Deviation
		V	V	V	%

The first four columns are measured results, the last two are for calculated values.

$U_{S,theory}$  is calculated using the formula above..

The deviation is found this way:

$$dev. = \frac{U_S - U_{S,theory}}{U_{S,theory}} \cdot 100 \%$$

### Discussion and evaluation

Is the voltage transformed up and down as expected?

How does the formula for the secondary voltage fit your results?

Does the percentage difference vary strongly, or is it of a fairly constant size?

Try to estimate the percentage of the field lines that don't go through the secondary coil on this specific transformer.

Apart from the UI core, other types of transformer cores exist – e.g. the so-called EI core.

On the Internet you can find pictures of an EI core and descriptions of how the windings are placed.

Which advantage can an EI transformer possibly have over one with a UI core?

## Teacher's notes

### Concepts used

Voltage  
Field lines

The concept of flux is not used but could eventually be introduced when working with the theory.

### Mathematical skills

Percent

### About the equipment

The voltmeter 381560 is overload protected. It will also tolerate wrong polarity although only positive values can be read.

When the core is not in place in the primary coil, the current can get so high that the coil overheats and the plastic coil former is damaged. The coils used have these maximum currents:

462510	200 windings	Max. 2 A
462520	400 windings	Max. 1 A
462525	800 windings	Max. 0.5 A

When mounted on the core, 462510 may still draw a current slightly larger than 2 A – if the power supply is turned fully up to 24 V (disrespecting the instructions in this manual). The coil can withstand this marginal overload for quite a long time.

When mounted on the UI core, neither 462520 nor 462525 can draw currents large enough to damage them.

## Detailed equipment list

### Specifically for this experiment

463000	UI core
462510	Coil f. student transformer, 200 turns
462520	Coil, 400 turns (2 are used)
462525	Coil, 800 turns
381560	Voltmeter

### Standard lab equipment

364000	Power supply (Many other models can be used but it is an advantage if it has a built-in voltmeter.)
105722	Safety cable, silicone, 50 cm yellow (2 pcs.)
105723	Safety cable, silicone, 50 cm blue (2 pcs.)