Solid-state physics

Magnetism

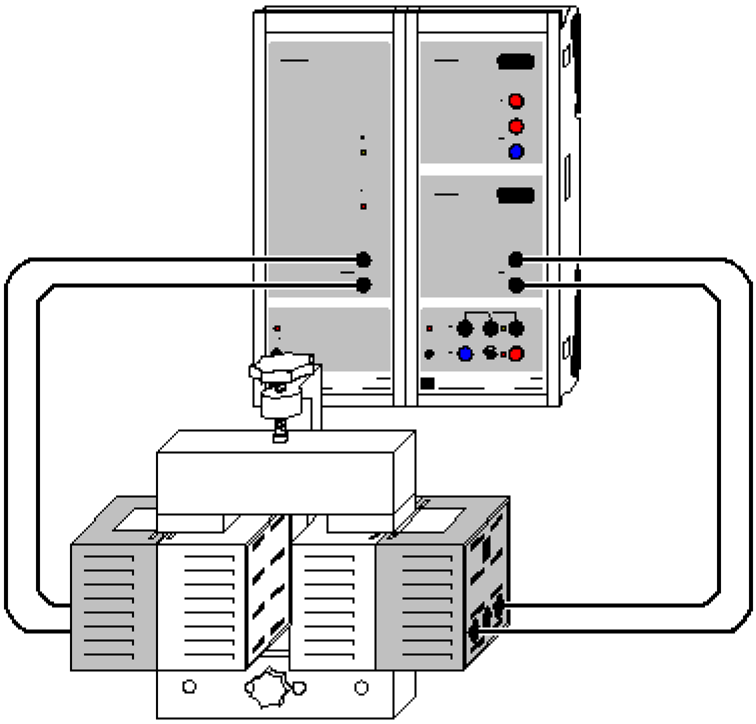
Ferromagnetic hysteresis

Recording the initial magnetization curve and the hysteresis curve of a ferromagnet

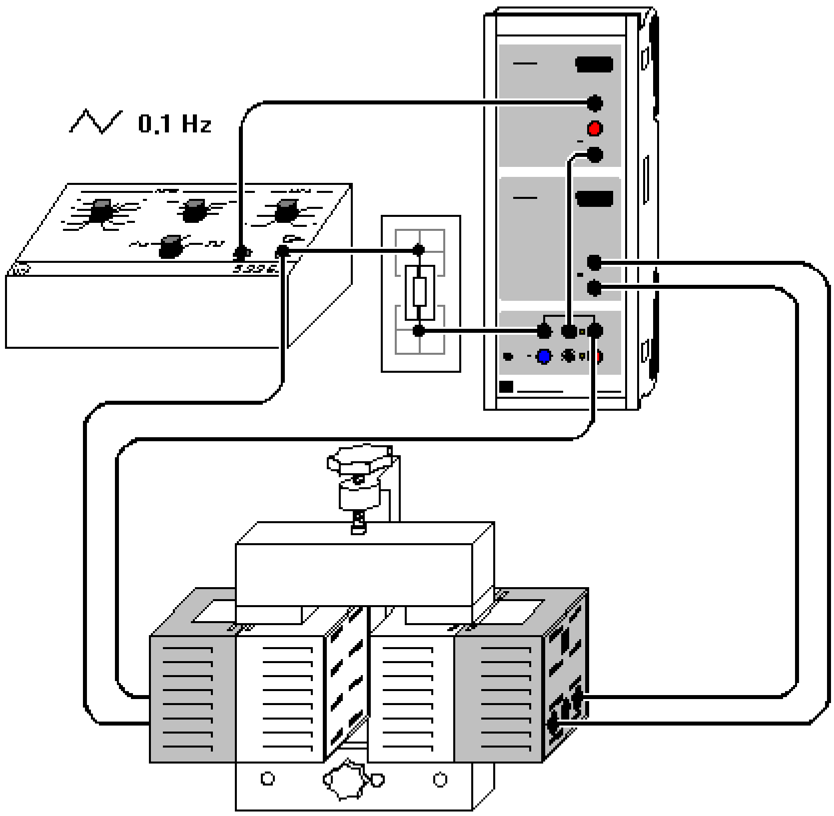
Description from CASSY Lab 2

For loading examples and settings, please use the CASSY Lab 2 help.

Hysteresis of a transformer core



Alternatively (without Power-CASSY):



Experiment description

In a transformer core (ferromagnet) the magnetic field

$H = N_1/L \cdot I$

is proportional to the coil current I and the effective turns density N_1/L of the primary coil. However, the generated magnetic flux density or magnetic induction

$B = \mu_r \cdot \mu_0 \cdot H$ (where $\mu_0 = 4\pi \cdot 10^{-7}$ Vs/Am)

is not proportional to H. Rather, it reaches a saturation value B_s as the magnetic field H increases. The relative permeability μ_r of the ferromagnet depends on the magnetic field strength H, and also on the previous magnetic treatment of the ferromagnet. In a demagnetized ferromagnet, the magnetic field strength is B = 0 T at H = 0 A/m. Normally however, a ferromagnet still retains a residual magnetic flux density B not equal to 0 T when H = 0 A/m (remanence).

Thus, it is common to represent the magnetic induction B in the form of a hysteresis curve as a function of the rising and falling field strength H. The hysteresis curve differs from the magnetization curve, which begins at the origin of the coordinate system and can only be measured for completely demagnetized material (H = 0 A/m, B = 0 T).

In this example H and B are not measured directly; rather, the quantities proportional to these, i.e. the primary current $I = L/N_1 \cdot H$ and magnetic flux $\Phi = N_2 \cdot A \cdot B$ through the secondary coil are used (N_2: number of turns of secondary coil; A: cross-section of ferromagnet). The magnetic flux Φ is calculated as the integral of the voltage U induced in the secondary coil.

Equipment list

1	Power-CASSY	524 011
1	Sensor-CASSY	524 010 or 524 013
1	CASSY Lab 2	524 220
1	U-core with yoke	562 11
1	Clamping device with spring clip	562 121
2	Coils with 500 turns	562 14
4	Connecting leads, 100 cm, black	500 444
1	PC with Windows XP/Vista/7/8	

Alternatively (without Power-CASSY)

1	Sensor-CASSY	524 010 or 524 013
1	CASSY Lab 2	524 220
1	U-core with yoke	562 11
1	Clamping device with spring clip	562 121
2	Coils with 500 turns	562 14
1	Function generator S12	522 621
1	STE resistor 1 Ω, 2 W	577 19
1	Socket board section	576 71
1	Connecting lead, 50 cm, black	500 424
7	Connecting leads, 100 cm, black	500 444
1	PC with Windows XP/Vista/7/8	

Experiment setup (see drawing)

Power-CASSY supplies the current for the primary coil of the transformer. The magnetic flux Φ is calculated from the induction voltage U of the secondary coil, which is measured at Sensor-CASSY input B.

Alternatively, you can perform the experiment without Power-CASSY, using the function generator S12. This apparatus must be set to sawtooth signal, frequency around 0.1 Hz and amplitude about 2 V. Recording of the magnetization curve is triggered at I = 0 A. To hit this point exactly, the current is shunted past the transformer by the relay and flows through a 1 Ω resistor prior to recording of the curve.

Carrying out the experiment

- Load settings
- Correct the offset if necessary: open Settings UB, select **Correct**, set the first target value 0 V and click on **Correct Offset**.
- Demagnetize the transformer core, e.g. by striking the end face of the yoke against the end faces of the U-core several times.
- Start the measurement with .

- Stop the measurement with ⏱ after one period of the hysteresis curve or at Φ = 0 Vs (in this case the core does not have to be demagnetized again).
- If the hysteresis curve lies in the second and fourth quadrants, reverse the connections on one of the two coils.
- If the display instrument U_B is overdriven during measurement (display flashes), extend the measuring range in Settings UB.

Evaluation

As the area of a hysteresis loop B(H)

$$\int B \cdot dH = \frac{E}{V}$$

just corresponds to the energy loss in remagnetization per volume V of the demagnetized material, the enclosed area in the diagram Φ(I)

$$\int \Phi \cdot dI = \int N_2 AB \cdot \frac{L}{N_1} \cdot dH = \frac{N_2}{N_1} V \int B \cdot dH = \frac{N_2}{N_1} \cdot E$$

gives us precisely the energy loss E of the remagnetization for N_1=N_2.

In the diagram, you can calculate this energy loss using "peak integration" of a hysteresis loop.