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STUDY OF FERROMAGNETIC HYSTERIZES CURVES IN CASSY LAB

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Abstract:
In this work, it is envisaged to increase the knowledge, skills and qualifications of students of technical education with laboratories related to physics. This is very important for our students to have the ability to use new technologies in the future and to quickly adapt to these technologies.

Keywords: hysteresis, magnetic field, current, voltage, measurement, inductive coil

The Main Part

Substances that have the property of magnetism even in the absence of an external field constitute a special class of magnetic materials. Since the most common type of such substances is iron, they are called ferromagnetic. Examples of ferromagnetic elements are iron, nickel, cobalt, gadolinium, and their alloys, as well as combinations of manganese and chromium with non-ferromagnetic elements.

The magnetization of weakly magnetic substances has a linear relationship with the field strength. The magnetization of ferromagnets is complexly connected with H. In addition to the non-linear connection between H and B, the phenomenon of hysteresis is also characteristic for ferromagnets. If we bring the magnetization to saturation (Figure 1 point 1) and reduce the magnetic field strength, then the magnetization will change along the initial 0-1 line. As a result, when the external field strength is zero, the magnetization is not lost, and the corresponding residual induction is characterized by the quantity called B_r. In this case, the magnetization J_r is called remanent magnetization.

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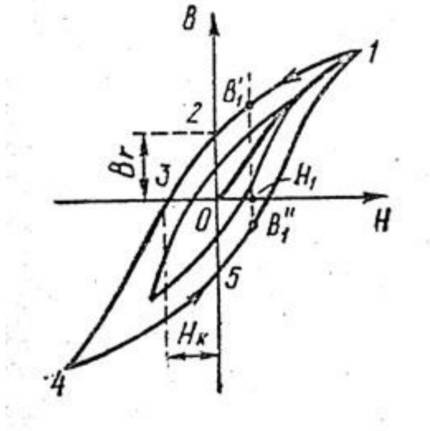


1-picture

Magnetization is lost under the influence of the field H_c, which is directed opposite to the field that creates magnetization. (3 points). H_c is called the coercive force.

B_r, H_c and μ_{max}values are the main characteristics of ferromagnets.

If the coercive force is large, such a ferromagnet is called a hard ferromagnet. It is characterized by a wide hysteresis surface. A soft ferromagnetic is used for a ferromagnetic with a small H_c, which creates a thin hysteresis surface.

When the current in the circuit changes, the following work is done against the self-induction E.U. force:

$dA' = (\varepsilon_s)idt = \frac{d\Psi}{dt}idt = id\Psi.$ (1)

(1) Expressing the expression through quantities characterizing the magnetic field, it is equal to $H = ni$, $\Psi = nlSdB$ for a long solenoid. From this $i = \frac{H}{n}$; $d\Psi = nlSdB$. writing in the form and putting these expressions in (1):

$dA' = HdB{\cdot}V$ (2)

will be fruitful. $V = lS \rightarrow$ area volume.

During one cycle of remagnetization of the hysteresis surface

$$\oint HdB$$

the surface enclosed by the integral surface is equal to S_c. Thus, the integral of the expression (2), i.e

$\oint dA'$ (3)

is different from zero. Therefore, in ferromagnets (2) work cannot be equated to the increase of magnetic field energy.

When calculating the work per unit volume of a ferromagnet, expression (2) is equal to:

$\oint HdB = S_c.$ (4)

At the end of the remagnetization cycle, H and B, the magnetic energy will also have their initial values. (4) work is not spent on generating the energy of the magnetic field, this work is spent on increasing the internal energy of the ferromagnet, i.e. heating it up.

In one cycle of remagnetization, work equal to the surface of the hysteresis surface (4) is spent on each unit of ferromagnetic volume. This work is spent on heating the ferromagnet.

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 $B = \mu_r \cdot \mu_o \cdot H$ (where $\mu_o = 4\pi \cdot 10^{-7}$ 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).

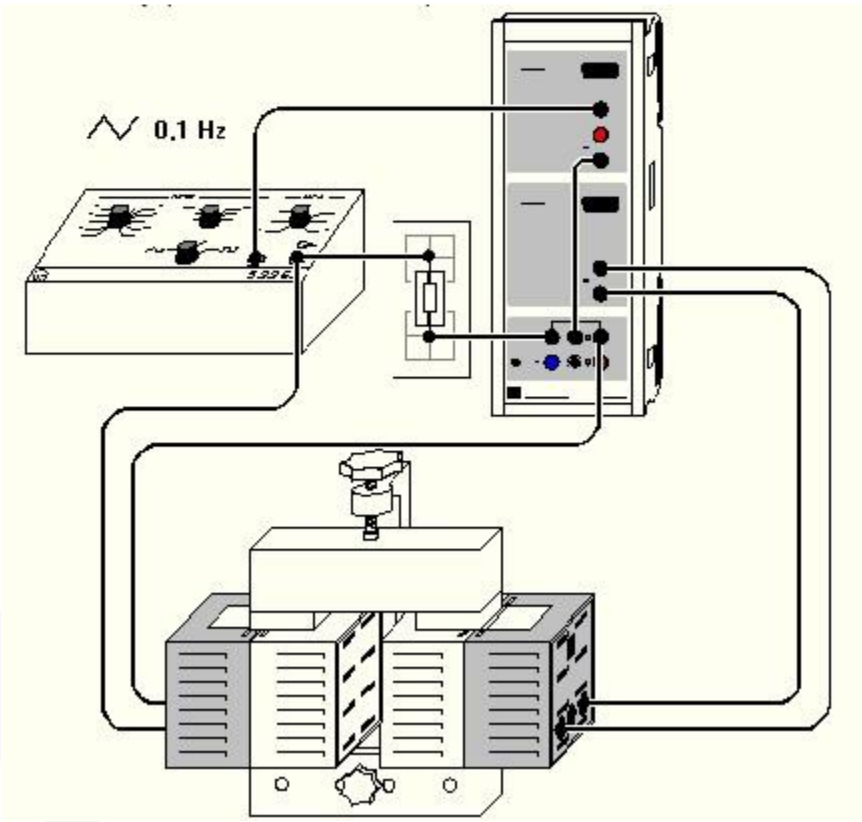
Thus, it is common to represent the magnetic induction B in the form of a hysteresis curve as a function of the rising and falling field strength H. The hysteresis curve differs from the magnetization curve, which begins at the origin of the coordinate system and can only be measured for completely demagnetized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

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 10 Ω resistor prior to recording of the curve.



2-picture

Carrying out the Experiment

Load settings (with Power-CASSY)

Load settings (without Power-CASSY)

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 F5

Stop the measurement with F5 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.

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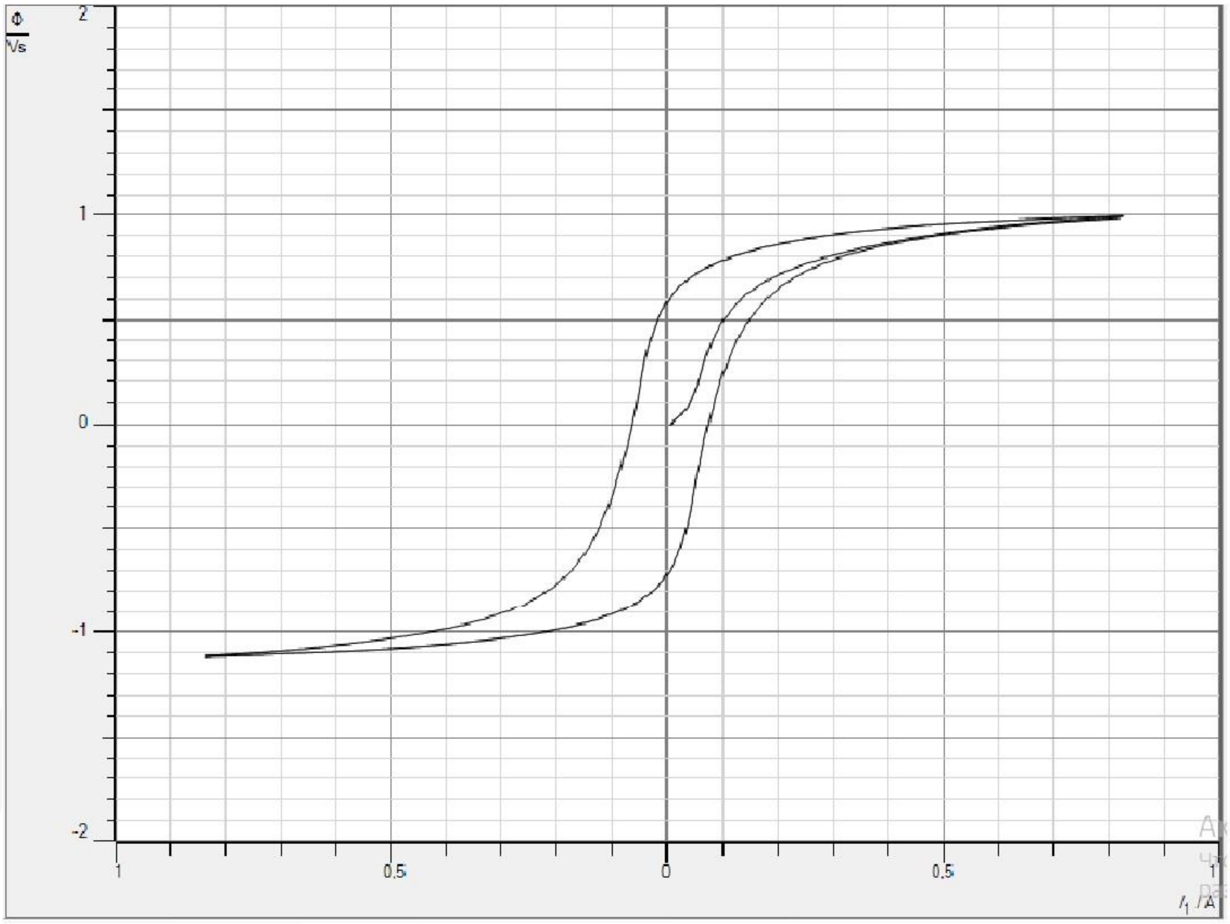

Summary
In this work, in addition to the magnetization of ferromagnets and the non-linear connection between H and B, the phenomenon of hysteresis for ferromagnets is also widely covered. The practical calculation of the hysteresis loop of ferromagnets with high accuracy was explained in the CASSY Lab program.

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