Related topics
Law of induction, magnetic flux, Maxwell's equations.

Principle
A permanent magnet falls with different velocities through a coil. The change in the magnetic flux Φ generates an induced voltage impulse. The induced voltage impulse U_{SS} is recorded with a computer interface system. Depending on the polarity of the permanent magnet the induced voltage impulse is negative or positive.

Equipment

Cobra3 Basic Unit	12150.00	1
Power supply, 12 V_	12151.99	1
RS232 data cable, 9 poles	14602.00	1
Cobra3 Universal Plotter Software	14504.61	1
Forked light barrier, compact	11207.20	1
Support rod, round, l = 600 mm	02037.00	1
Boss head	02043.00	3
Tripod, -PASS-	02002.55	1
Universal clamp	37715.00	1
Glass tube, l = 300 mm	45126.01	1
Coil holder	06528.00	1
Coil, 600 turns, short	06522.01	1
Magnet, d = 8 mm, l = 60 mm	06317.00	1
Connecting cord, 32 A, l = 50 cm, red	07361.01	2
Connecting cord, 32 A, l = 50 cm, blue	07361.04	2
Connecting cord, 32 A, l = 50 cm, yellow	07361.02	1
PC, Windows® 95 or higher		

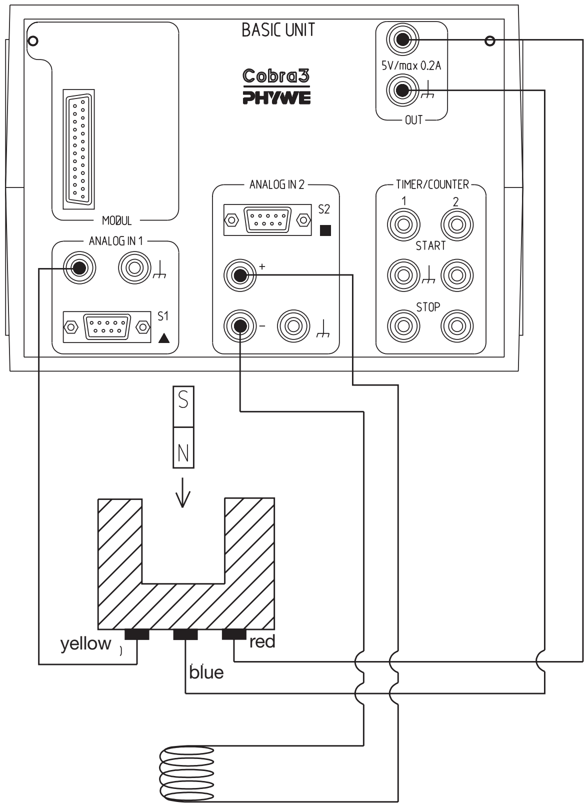
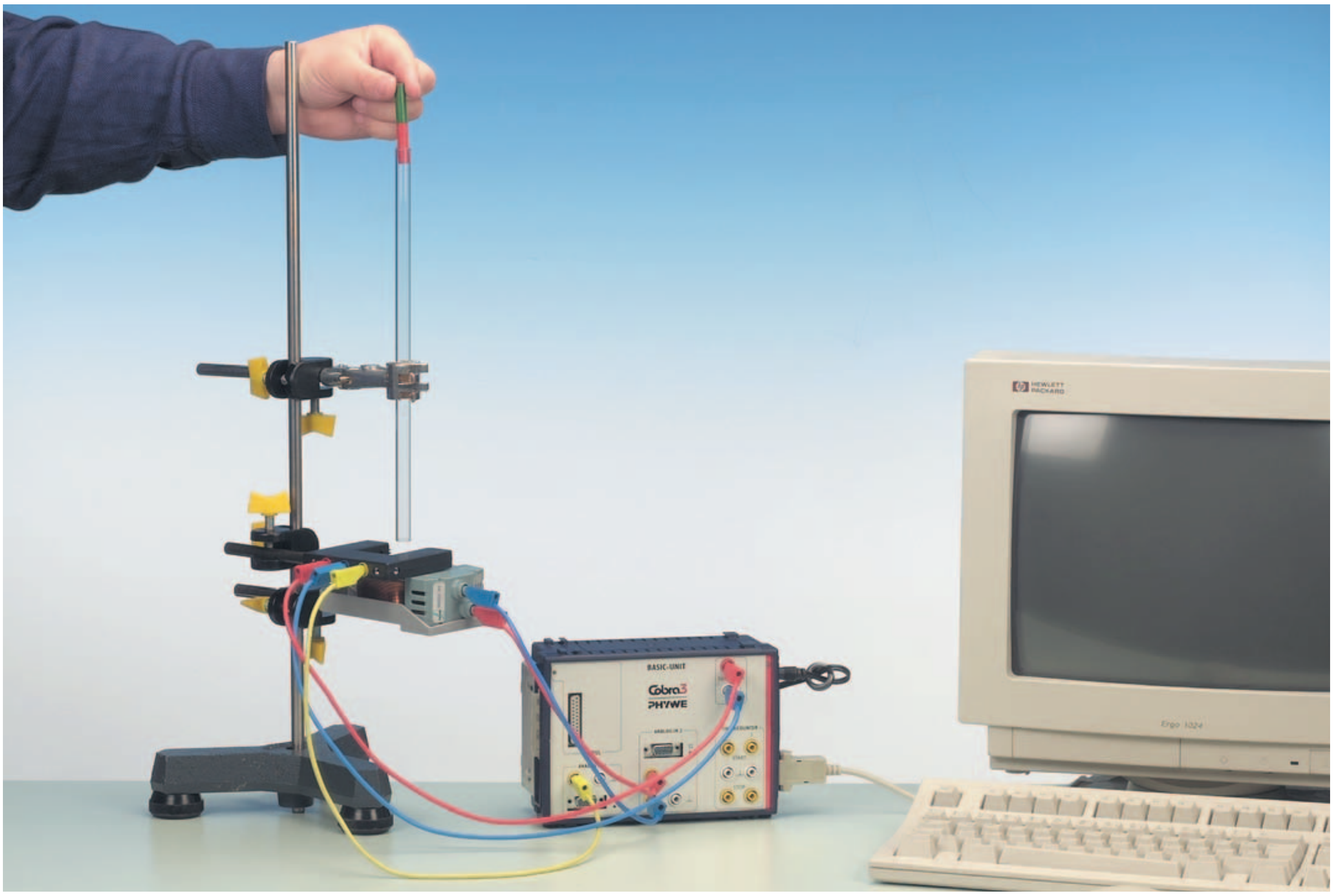


Fig. 2. Circuit diagram

Fig. 1. Experimental set-up



Induction impulse with Cobra3

Tasks

1. Measurement of the induced voltage impulse U_{SS} and the velocity of the falling magnet.
2. Evaluation of the induced voltage impulse U_{SS} as a function of the velocity of the magnet.
3. Calculation of the magnetic flux induced by the falling magnet as a function of the velocity of the magnet.

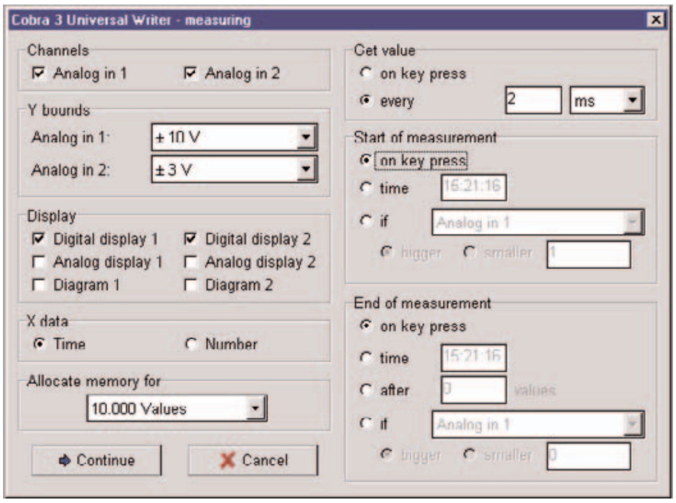
Set-up

– According to Figs. 1 and 2.
– Adjust the light barrier in a such a manner that it is located directly above the coil The magnet must interrupt the light beam during its fall.
– The glass tube provides the magnet with reliable guidance and also insures a stable spinless fall even at larger fall heights.

Procedure

– Initiate recording of the measured values using parameters in accordance with Fig. 3.
– Depress the ”Start measurement” button.
– Introduce the tip of the magnet in the glass tube, let it fall, catch it with one hand under the coil and manually terminate the measurement recording procedure.
– Measure the interruption period of the signal from channel IN 1 (light barrier) using the ”Survey” icon (Fig. 4). In this case: $\Delta x = \Delta t$ = 26.2 ms. With a magnet length of l = 6 cm, it follows that the velocity immediately before the magnet enters the coil is $v = l / \Delta t$ = 2.29 m/s.

Fig. 3. Measurement parameters



– Also using the ”Survey” icon, measure the total amplitude U_{SS} (peak to peak) of the induction voltage (Fig. 5); in this case: $U_{SS} = \Delta y$ = 2.764 V.
– Mark unnecessary parts of the curve before and after the induction pulse and cut them out with the ”Cut” icon.
– Mark the positive (F_1) and the negative (F_2) parts of the curve separately (cf. Fig. 7). Calculate the areas with the ”Show integral” icon. Finally, add the values of the two partial areas (Fig. 6).

Results

– For induced voltage U the following is true:

$$U = -n \frac{\mathrm{d}\phi}{\mathrm{d}t}$$

where
n = Number of windings in the coil
Φ = Magnetic flux
t = Time

Integration provides the following:

$$\phi = -\frac{1}{n} \int U \,\mathrm{d}t = B \cdot A$$

where
B = Value of the magnetic flux density
A = Cross sectional area of the coil

Fig. 5. Determination of the induction voltage U_{SS}

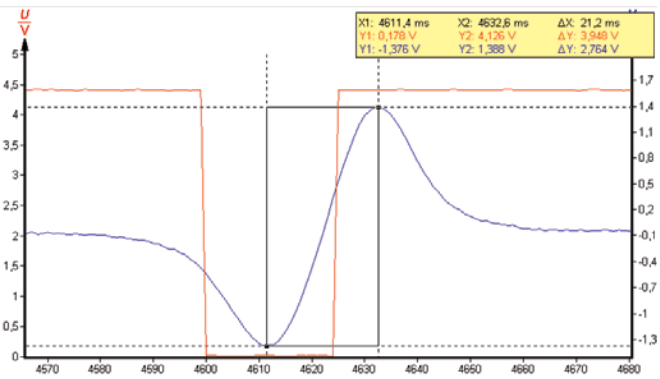


Fig. 4. Determination of the magnet’s falling velocity

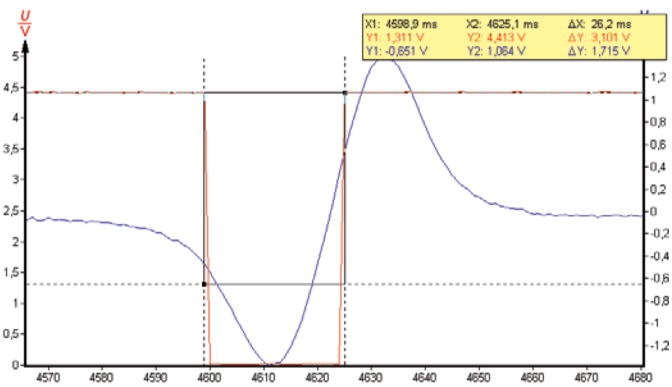
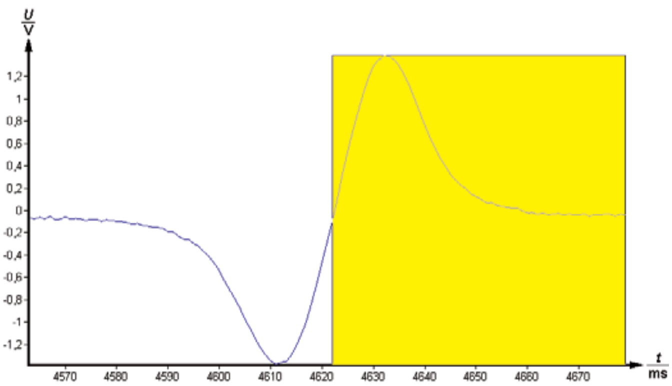


Fig. 6. Calculation of the magnetic induction



– Plot U_{SS} versus the falling velocity v of the magnet (Fig. 8). It is apparent that the induced voltage is proportional to the velocity: $U_{ind} \sim d\Phi/dt$.

— It follows from Fig. 9 that the integral of the induced voltage is a constant which is not a function of the velocity of field change:

$$\Phi = B\ A$$

Remarks

— The curves in Figs. 4 to 6 are clearly asymmetrical, in particular for small falling heights. This is due to the non-constant velocity of the magnet on falling through the coil.

— When the polarity of the magnet reverses, the sign of the induction voltage changes and thus the course of the curve.

Fig. 8. Amplitude of the induced voltage U_{SS} as a function of the magnet's falling velocity v

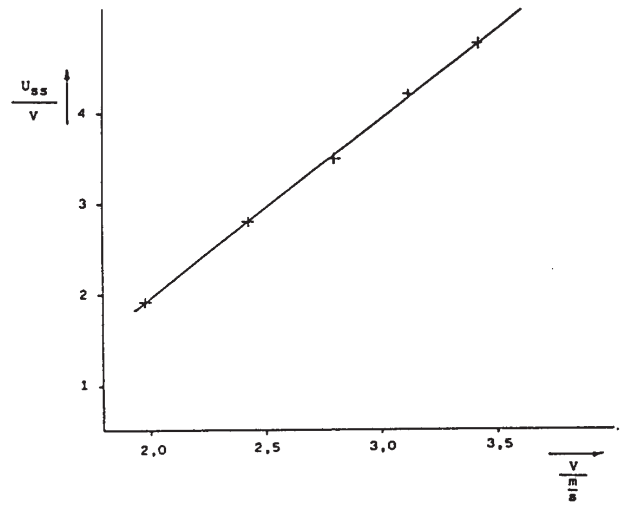


Fig. 7. Principle of the calculation of the magnetic induction

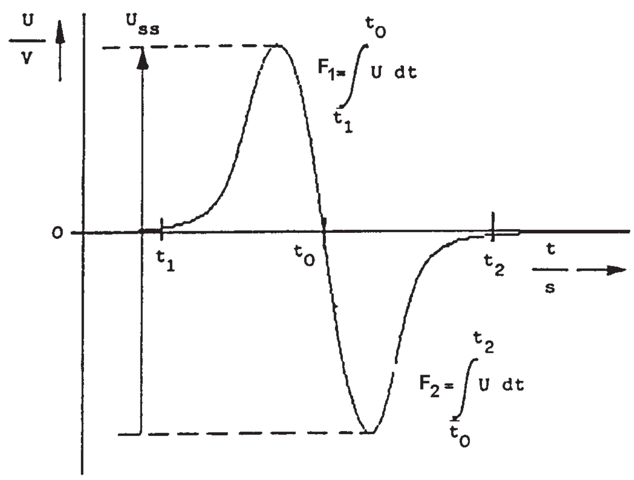


Fig. 9. Magnetic flux Φ, determined from measurement curves according to Fig. 6, for differing magnet velocities