Exercise B

Two permanent magnets having the shape of rectangular parallelepipeds with sides 50 mm, 20 mm and 8 mm are hidden in a block of polystyrene foam with dimension 50 cm, 31 cm and 4.0 cm. Their sides are parallel to the sides of the block. One of the hidden magnets (A) is positioned so that its $\vec{B}$ (Fig. 15) points in z direction and the other (B) with its $\vec{B}$ in x or y direction (Fig. 15).

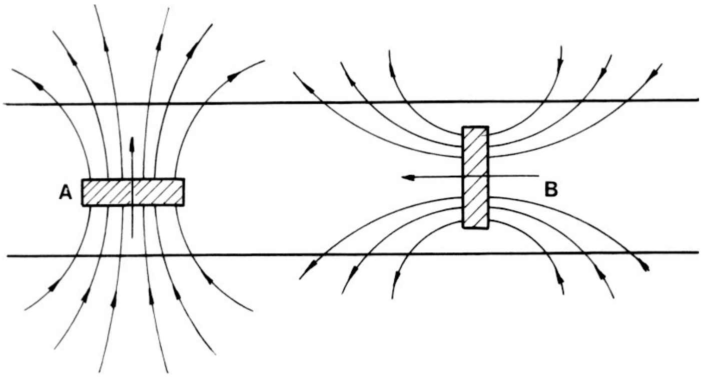

Fig. 15 A typical implementation of the magnets in the block

The positions and the orientations of the magnets should be determined on the basis of observations of forces acting on the extra magnet. The best way to do this is to hang the extra magnet on the thread and move it above the surface to be explored. Three areas of strong forces are revealed when the extra magnet is in the horizontal position i. e. its $\vec{B}$ is parallel to z axis, suggesting that three magnets are hidden. Two of these areas producing an attractive force in position P (Fig. 16) and a repulsive force in position R are closely together.

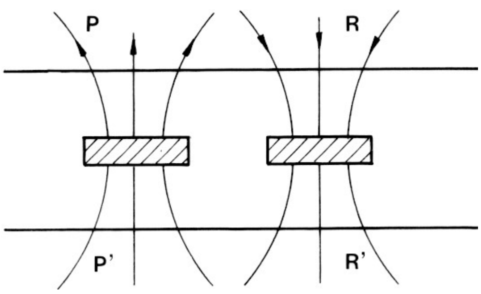

Fig: 16 Two 'ghost' magnets appearing in the place of magnet B

However, by inspecting the situation on the other side of the block, again an attractive force in area P' is found, and a repulsive one in area R'. This is in the contradiction with the supposed magnets layout in Fig. 16 but corresponds to the force distribution of magnet B in Fig. 15.

To determine the z position of the hidden magnets one has to measure the z component of $\vec{B}$ on the surface of the block and compare it to the measurement of B_z of the extra magnet as a function of distance from its center (Fig. 18). To achieve this the induction coil of the measuring system is removed from the point in which the magnetic field is measured to a distance in which the magnetic field is practically zero, and the peak voltage is measured.

In order to make the absolute calibration of the measuring system, the response of the system to the known magnetic field should be measured. The best defined magnetic field is produced in the gap between two field generating coils. The experimental layout is displayed in Fig. 17.

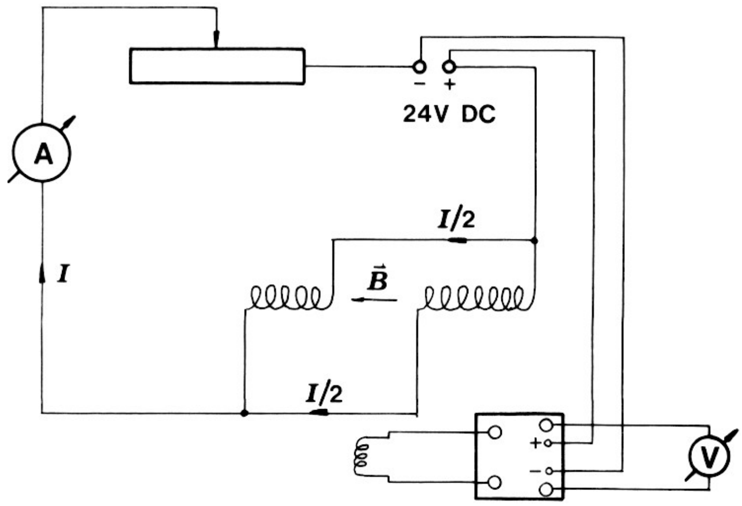

Fig. 17 Calibration of the measuring system

The magnetic induction in the gap between the field generating coils is calculated using the formula:

$$B = \frac{\mu_O NI}{(2l + d)}\,.$$

Here N is the number of the turns of one of the coils, l its length , d the width of the gap, and I the current through the ammeter. The peak voltage, U, is measured when the induction coil is removed from the gap.

Plotting the magnetic induction B as a function of peak voltage, we can determine the sensitivity of our measuring system:

$$\frac{B}{U} = 0.020\ \mathrm{T/V}\,.$$

(More precise calculation of the magnetic field in the gap, which is beyond the scope of the exercise, shows that the true value is only 60 % of the value calculated above.)

The greatest value of B is 0.21 T.

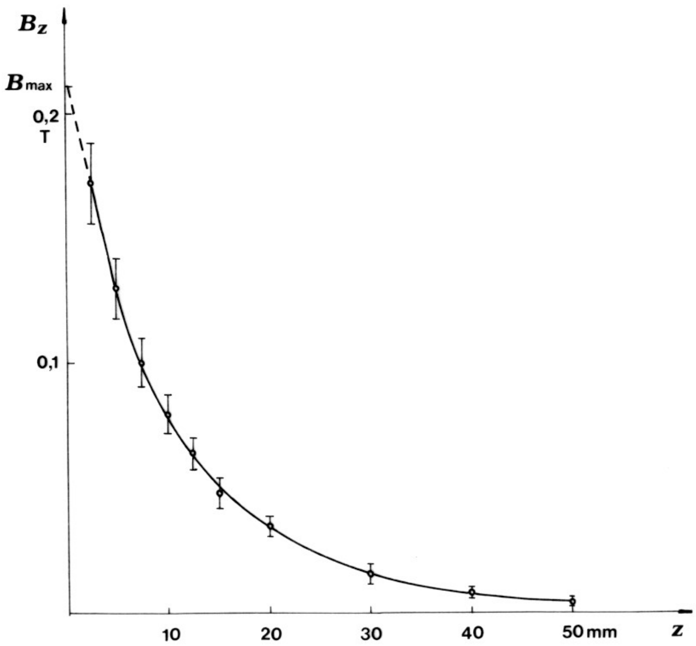

Fig. 18 Magnetic induction vs. distance

Marking scheme:

a) determination of x, y position of magnets (±1 cm) 1 p.

b) determination of the orientations 1 p.

c) depth of magnets (±4 mm) 2 p.

d) calibration (±50 %) 3 p.

e) mapping of the magnetic field 2 p.

f) determination of $B_{\max}$ (±50 %) 1 p.

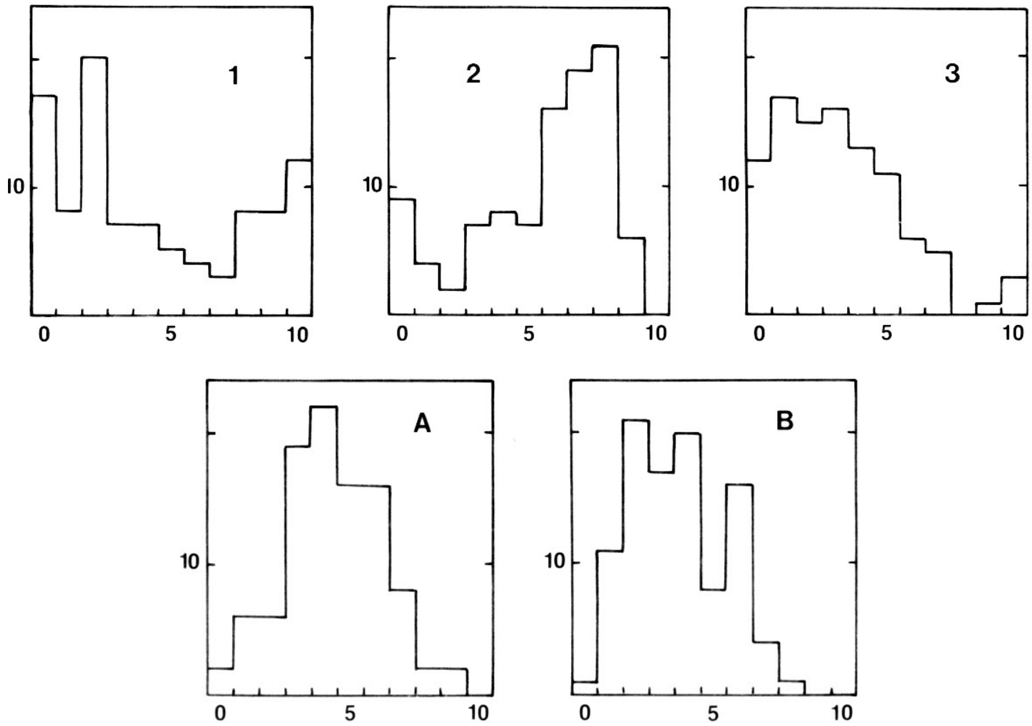

Fig. 19 Distribution of marks for the theoretical (1,2,3) and the experimental exercises. The highest mark for each exercise is 10 points.