MAGNETIC FORCE

- Measures Magnetic Moment by Magnetic Force
- Measures dB/dz vs z for a current loop
- Resolves Pervasive E&M Misconceptions

Magnetic Force, MF1-A, is a hands-on instrument designed to explore the forces on a permanent magnetic dipole caused by external magnetic fields. Essentially all introductory texts discuss magnetic forces on dipoles, yet students have not had an opportunity to perform either qualitative or quantitative experiments with this interaction.

Magnetic Force uses a small neodymium-iron-boron permanently magnetized disk as a model system for an ideal dipole moment, and a pair of Helmholtz coils to create the external magnetic fields. The various experiments using MF1-A are appropriate for both high school and university students. From TeachSpin's extensive experience demonstrating Magnetic Torque, Mτ 1-A, we are convinced that the Magnetic Force experiments will not only surprise (even amaze) most students, but will also serve to clear up one of the most pervasive physics misconceptions in E&M. We have developed this affordable apparatus in order to give students concrete learning experiences with magnetic forces.

THE INSTRUMENT

The apparatus consists of a pair of coils in the Helmholtz configuration and a small magnetized disk mounted in a gimbal which allows it to rotate. The gimbal is suspended from a spring, as shown in the photograph. The deflection of the spring is used to measure the magnetic force on the magnetized disk.

The spring obeys Hooke's Law. It is calibrated by attaching one gram steel ball bearings. The coils can be used individually or connected in series two different ways: (1) to provide a ***uniform*** axial field at the midpoint between the coils and (2) to produce a ***field gradient*** in the same region.

OBJECTIVES

I. To demonstrate that ***no net magnetic force*** acts on a magnetic dipole in a region of ***uniform*** magnetic field. For these experiments, the coils are connected in series with the current circulating in the same direction in both coils.

In the presence of a uniform field of 65 gauss, the spring does not elongate or compress. This almost always surprises students who expect the dipole to move up or down depending on the orientation of the dipole with respect to the field. The observation that the dipole only rotates to align itself along the field makes the students reconsider their preconceived ideas about magnetism.

Instruments Designed For Teaching

TEACH SPIN

II. To show that a net magnetic force on a dipole exists only in the presence of a ***magnetic field gradient,*** a spatially varying field. For these experiments, the coils are connected in series with the currents flowing in ***opposite*** directions, creating a magnetic field gradient along the axis.

III. To determine the magnitude of the magnetic moment of the dipole by measuring the magnetic force in the field gradient dB/dz. The basic physics relationship is:

$$F_{magnetic} = \mu \frac{dB}{dz}$$

IV. To examine the axial magnetic field ***gradient*** of a ***single*** current carrying the loop.

MEASUREMENTS

Determining Magnetic Moment

The magnitude of the magnetic moment of the dipole can be obtained from the slope of the curve plotted in Figure 1. The force is found by calibrating the spring. The theoretical calculation of the field gradient in terms of the current through the coils and known dimensions is straightforward. It can be supplied by the instructor or derived by the student by differentiating the expression for the axial magnetic field of a loop of current. Student data is shown in Figure 1.

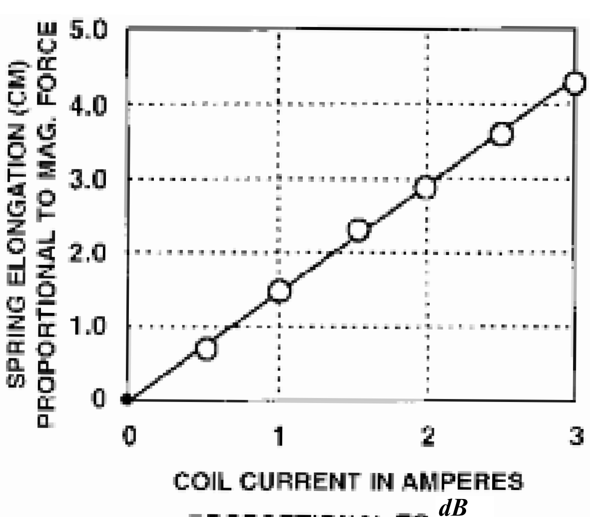

Figure 1

An independent measurement of the magnetic moment of the magnetized disk can be made with TeachSpin's Hall Effect probe, HE1-A. This device can measure the $1/z^3$ dependence of the magnetic field of the dipole along its axis. From these measurements, the magnitude of μ can be calculated and compared with the magnetic force measurements.

Graphing the Field Gradient

The axial magnetic field of a loop of current is discussed in every introductory text as an application of the Biot-Savart Law. The gradient of this field can be calculated by straightforward differentiation. The magnitude of the field gradient can be determined experimentally from the magnetic force on a dipole. Figure 2 shows student data for 3 amperes through the upper coil only. The theoretical curve is superimposed on the same plot.

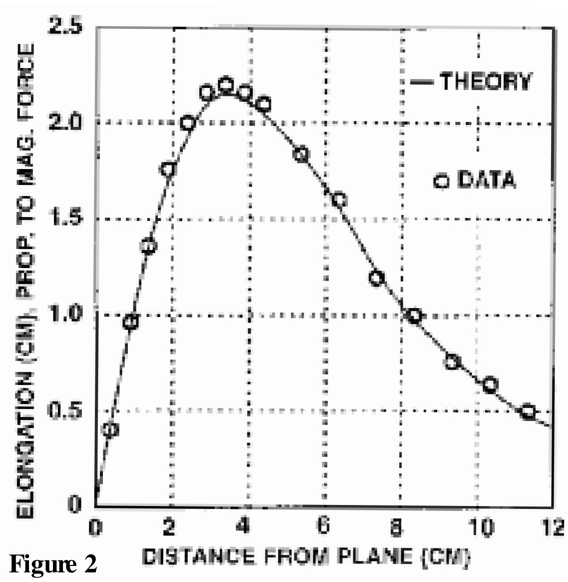

Figure 2

SPECIFICATIONS

168 turns/coil Mean Radius: 7.0 cm

Separation: 7.0 cm (Helmholtz condition)

Resistance: 2.8 Ω/coil   Current: 0-3 Amps

Magnetic Moment ≈ 4 A-m^2

Spring Constant: 1 N/M

Warranty: Two years, parts and labor

Patent Number 5,846,088

TEACHSPIN, INC.
45 Penhurst Park, Buffalo NY 14222-1013
Phone/Fax 716-885-4701   www.teachspin.com