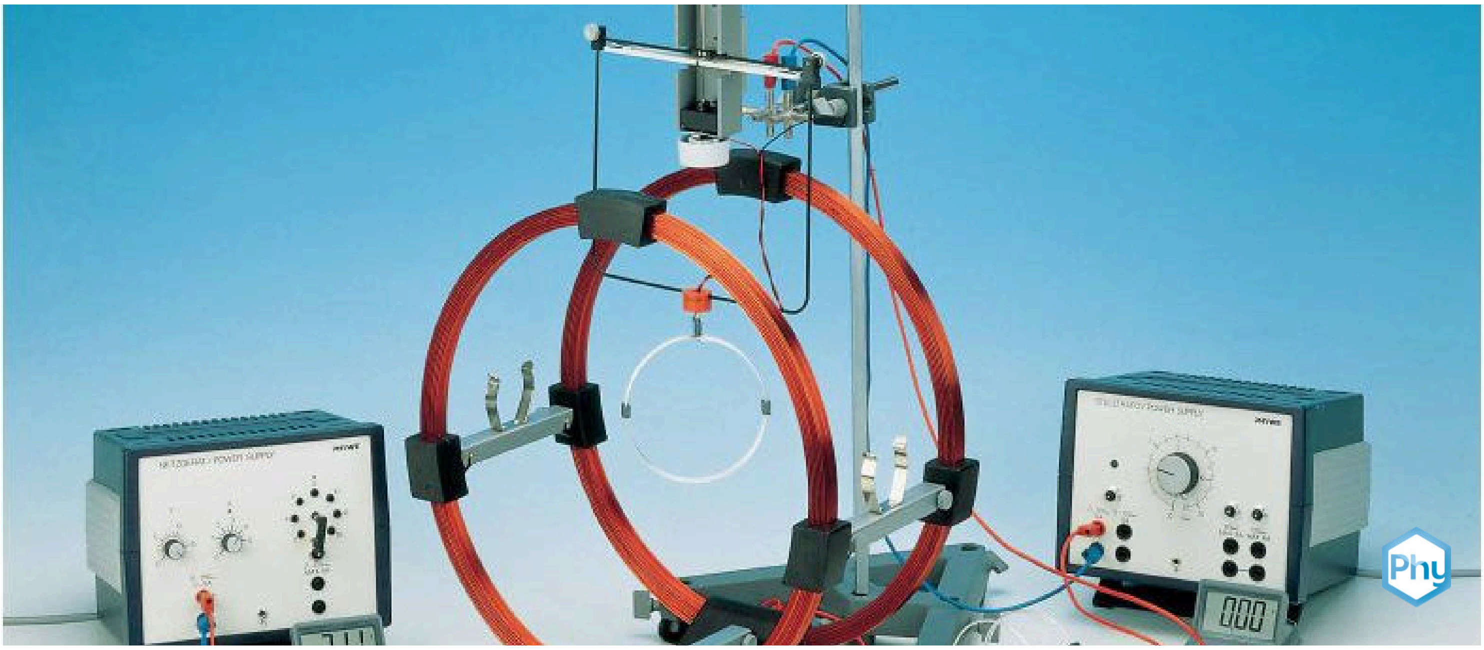
Magnetic moment in the magnetic field



The goal of this experiment is to investigate the magnetic moment in a magnetic field.

Physics | Electricity & Magnetism | Magnetism & magnetic field

Difficulty level	Group size	Preparation time	Execution time
hard	2	45+ minutes	45+ minutes

This content can also be found online at:

http://localhost:1337/c/607fee085b8eeb00039b8274

General information

Application

Setup

The magnetic moment is the magnetic strength and orientation of a magnet or other object that produces a magnetic field. Examples of objects that have magnetic moments include: loops of electric current (such as electromagnets), permanent magnets, elementary particles (such as electrons), various molecules, and many astronomical objects (such as many planets, some moons, stars, etc.).

Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Other information (1/2)

PHYWE

Prior knowledge

No prior knowledge is required.

Scientific principle

A conductor loop carrying a current in a uniform magnetic field experiences a torque. This is determined as a function of the radius, of the number of turns and the current in the conductor loop and of the strength of the external field.

Other information (2/2)

PHYWE

Learning objective

The goal of this experiment is to investigate the magnetic moment in a magnetic field.

Tasks

Determination of the torque due to a magnetic moment in a uniform magnetic field, as a function

1. of the strength of the magnetic field,
2. of the angle between the magnetic field in the magnetic moment,
3. of the strength of the magnetic moment.

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Theory (1/2)

PHYWE

With a closed conductor loop C, through which there flows a current I, a magnetic moment $\vec{m}$ is defined:

$$\vec{m} = \frac{I}{2} \oint_C \vec{r} \times d\vec{r} = I \oint_A d\vec{\Omega}$$

A is any given area, the boundary of which is C. A magnetic field with flux density $\vec{B}$ exerts a torque $\vec{T}$ on a magnetic moment.

$$\vec{T} = \vec{m} \times \vec{B} \quad (1)$$

If the magnetic field varies with position, the individual parts of the conductor loop are subjected to different torques. It is therefore desirable to bring the conductor loop into a uniform magnetic field. Two coils, set up as shown in Fig. 1 and whose radius is equal to the distance between them (Helmholtz arrangement), are used to produce a uniform magnetic field.

Theory (2/2)

PHYWE

For the present case, in which the conductor loop is a flat current ring with diameter d and n turns,

$$\vec{m} = I \cdot n \cdot \vec{A} \quad (2)$$

$$|\vec{m}| = I \cdot n \cdot (\frac{\pi}{4}) d^2$$

where $\vec{A}$ is the vector of the area of the current ring.

If a current I°′ flows in the Helmholtz coils, then, from (1):

$$|\vec{T}| = c \cdot I \cdot n |\vec{A}| I' \cdot \sin\alpha \quad (3)$$

where α is the angle between $\vec{B}$ and the plane vector $\vec{A}$, and c is a constant of these Helmholtz coils.

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Equipment

Position	Material	Item No.	Quantity
1	Helmholtz coils, one pair	06960-06	1
2	Conductors, circular, set	06404-00	1
3	Torsion dynamometer, 0.01 N	02416-00	1
4	Coil holder for 02416-00	02416-02	1
5	Distributor	06024-00	1
6	PHYWE Power supply, universal, analogue display DC: 18 V, 5 A / AC: 15 V, 5 A	13503-93	1
7	PHYWE Variable transformer with digital display DC: 0...20 V, 12 A / AC: 0...25 V, 12 A	13542-93	1
8	Digital multimeter, 600V AC/DC, 10A AC/DC, 20 MΩ, 200 µF, 20 kHz, −20°C… 760°C	07122-00	2
9	Support base DEMO	02007-55	1
10	Support rod, stainless steel, 750 mm	02033-00	1
11	Right angle clamp expert	02054-00	2
12	Connecting cord, 32 A, 750 mm, red	07362-01	5
13	Connecting cord, 32 A, 750 mm, blue	07362-04	5

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Setup and Procedure

Setup and Procedure (1/2)

The experimental set-up is as shown in Fig. 1. Series connection is recommended so that the same magnetic field is induced in both coils. In the Helmholtz arrangement which can be built up with the spacing cross-members supplied, the coils are arranged reversed, so that the connections 1-1 or 2-2 should be joined (for series connection). In continuous operation the current in the Helmholtz coils should not exceed 3 A.

The connection wires to the coil carrier should hang loosely. They should be twisted together, so that no additional moment is produced.

Fig. 1: Experimental setup

Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Setup and Procedure (2/2)

PHYWE

The zero-point of the torsion balance should be checked frequently, since rapid rotary movements can displace the connecting leads.

Very small torques occur when measuring torque as a function of the Helmholtz coil current and of the angle. It is therefore recommended to use only the coil with 3 turns and to increase the coil current briefly (approx. To 6).

The angles should be set at 15° intervals, by alternate use of the notches in the coil carrier.

PHYWE

Evaluation

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Results (1/3)

PHYWE

The exponents of the different experimental set ups shown in table 1 are proving the equations mentioned in the theory section.

Table 1

Fig.	Exponent	Standard Error	Equation
2	1.006	$\pm$0.008	3
3	0.988	$\pm$0.009	3
5	0.99	$\pm$0.01	3
6	1.94	$\pm$0.03	2, 3

From the regression line to the measured values of Fig. 2, with the exponential statement

$$Y = A \cdot X^B$$

the results are listed in Table 1.

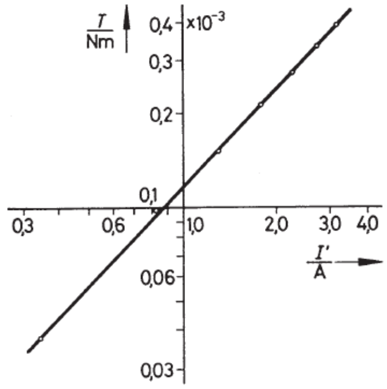


Fig. 2: Torque due to a magnetic moment in a uniform magnetic field as a function of the current I' (Helmholtz coils), in accordance with Equation (3).

Results (2/3)

PHYWE

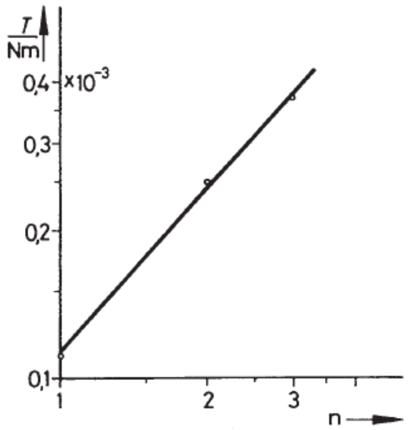


Fig. 3: Torque due to a magnetic moment in a uniform magnetic field as a function of the number of turns n, in accordance with Equation (3).

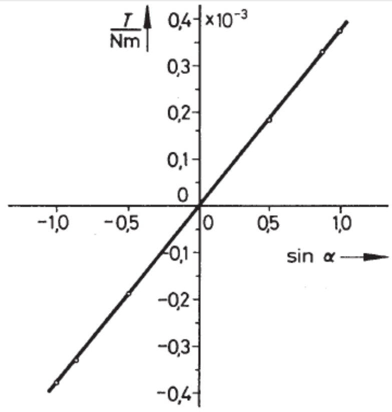


Fig. 4: Torque due to a magnetic moment in a uniform magnetic field as a function of the angle between the magnetic field and magnetic moment.

PHYWE
Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Results (3/3)

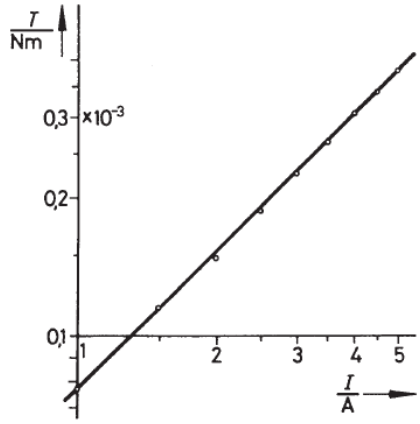


Fig. 5: Torque due to a magnetic moment in a uniform magnetic field as a function of the coil current I, in accordance with Equation (2).

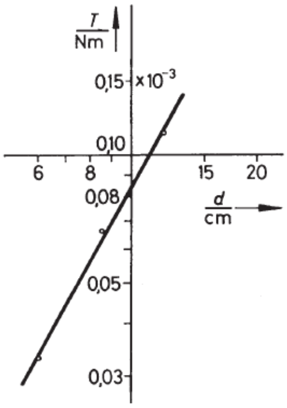


Fig. 6: Torque due to a magnetic moment in a uniform magnetic field as a function of the diameter d, in accordance with Equation (2).

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de