Magnetic moment in the magnetic field

Related topics

Torque, magnetic flux, uniform magnetic field, Helmholtz coil.

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.

Equipment

Pair of Helmholtz coils	06960.00	1
Conductors, circular, set	06404.00	1
Torsion dynamometer, 0.01 N	02416.00	1
Coil holder for 02416.00	02416.02	1
Distributor	06024.00	1
Power supply, universal	13500.93	1
Power supply var. 15 VAC/12 VDC/5 A	13530.93	1
Digital multimeter	07134.00	2
Support base -PASS-	02005.55	1
Support rod -PASS-, square, l = 630 mm	02027.55	1
Right angle clamp -PASS-	02040.55	2
Connecting cord, l = 750 mm, red	07362.01	5
Connecting cord, l = 750 mm, blue	07362.04	5

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.

Set-up and procedure

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 set-up for determining the torque due to a magnetic moment in the magnetic field.

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.

Theory and evaluation

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

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

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.

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

If the magnetic field varies with position, the individual parts of the conductor loop are subjectet 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.

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

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

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):

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

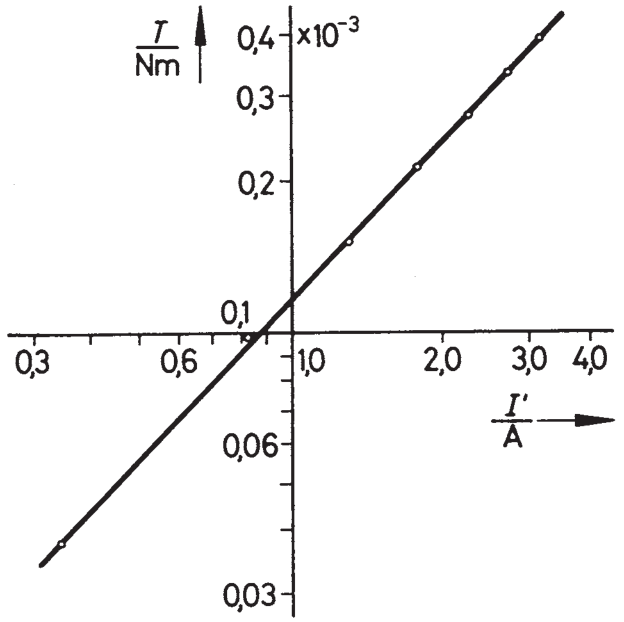
where α is the angle between $\vec{B}$ and the plane vector $\vec{A}$, and c is a constant of these Helmholtz coils.

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

Table 1

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

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).



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.

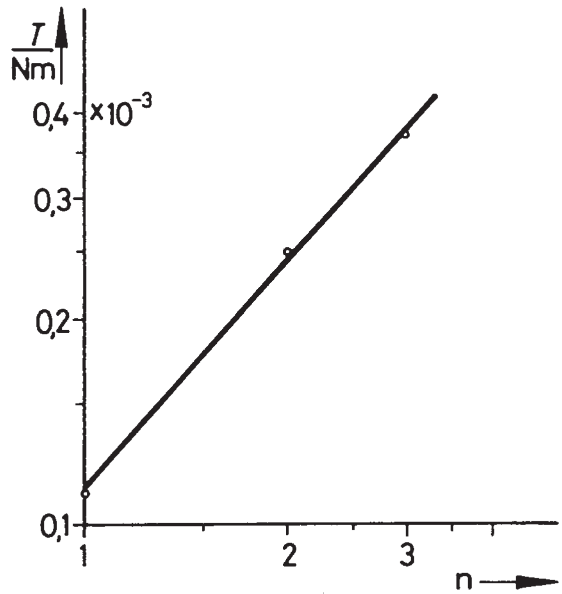


Fig. 3: Torque due to a magnetic moment in a uniform magnetic field as a function of the number of turns n, in accordance with Equation (3).

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.

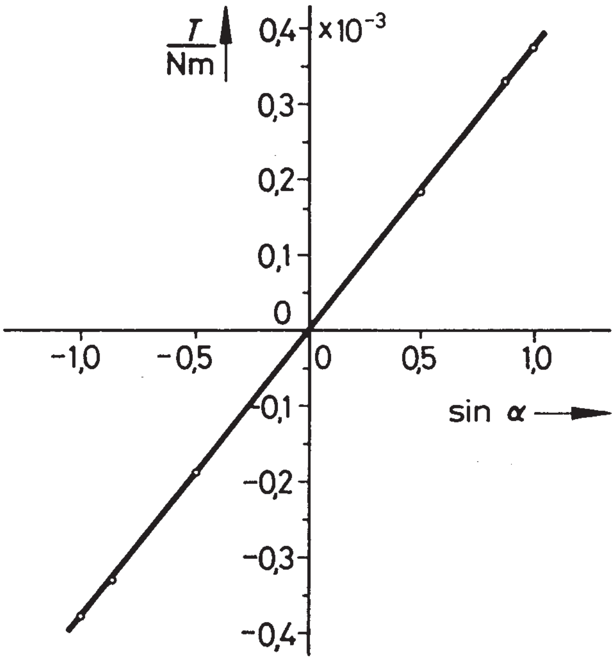
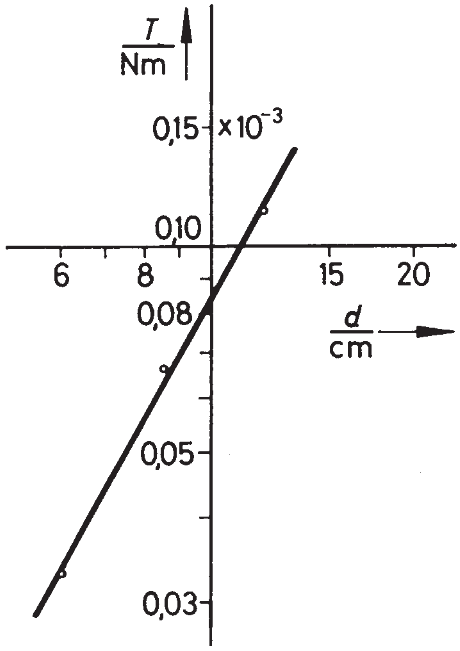


Fig. 6: Torque due to a magnetic moment in a uniform magnetic field as a function of the diameter d, in accordance with Equation (2).



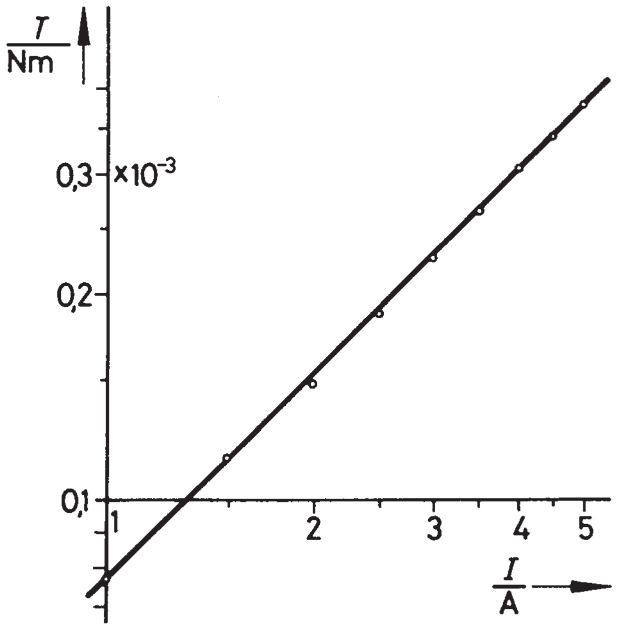


Fig. 5: Torque due to a magnetic moment in a uniform magnetic field as a function of the coil current I, in accordance with Equation (2).