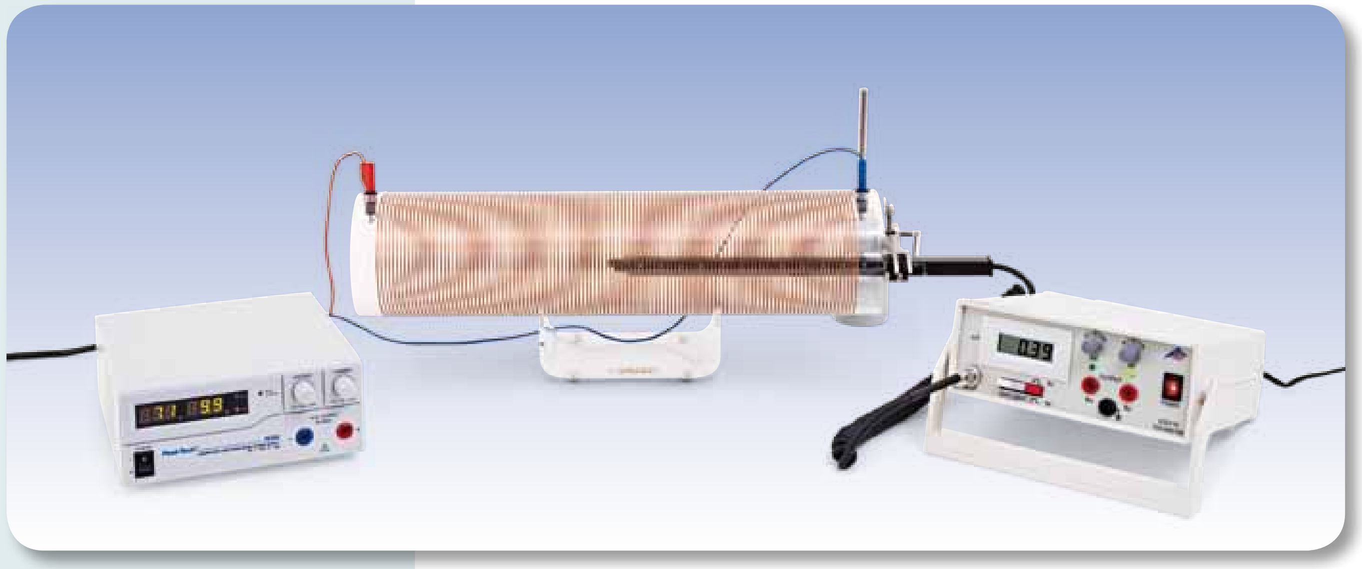
MAGNETIC FIELD OF A CYLINDRICAL COIL



EXPERIMENT PROCEDURE

- **Determine the magnetic flux density *B* inside a cylindrical coil as a function of the current *I*.**
- **Measure the magnetic flux density *B* inside a cylindrical coil with coils that can be moved closer together or farther apart as a function of the current *I*.**
- **Determine that for long coils, the magnetic flux density is proportional to the density of the windings (how close they are together).**

OBJECTIVE

Determine the magnetic field generated by coils of various lengths.

SUMMARY

The magnetic flux density inside a long cylindrical coil is directly proportional to the current through the coil and how close together the coil windings are, but is not dependent on the radius of the coil as long as the length of the coil is comparatively much greater than its diameter. That will be demonstrated in this experiment using two coils of different diameter and another coil in which the separation of the coil windings can be increased or decreased.

REQUIRED APPARATUS

Quantity	Description	Number
1	Field Coil 100 mm	**1000591**
1	Field Coil 120 mm	**1000592**
1	Coil with Variable Number of Turns per Unit Length	**1000965**
1	Stand for Cylindrical Coils	**1000964**
1	Teslameter 200 mT (230 V, 50/60 Hz)	**1003314 or**
	Teslameter 200 mT (115 V, 50/60 Hz)	**1003313**
1	DC Power Supply, 1 – 32 V, 0 – 20 A (115 V, 50/60 Hz)	**1012858 or**
	DC Power Supply, 1 – 32 V, 0 – 20 A (230 V, 50/60 Hz)	**1012857**
1	Set of 15 Experiment Leads, 75 cm 2.5 mm²	**1002841**
1	Barrel Foot, 1000 g	**1002834**
1	Stainless Steel Rod 250 mm	**1002933**
1	Universal Clamp	**1002830**
1	Universal Jaw Clamp	**1002833**

GENERAL PRINCIPLES

The Biot-Savart law describes the relationship between magnetic flux density *B* and electric current *I* through a conductor of any arbitrary geometry. The calculation involves adding the contributions of infinitesimally small sections of conductor to find the overall magnetic flux density. The overall field is then determined by integrating over the geometry of the conductor. In some cases, e.g. for a long cylindrical coil, there is a simple analytical solution to this integration.

According to the Biot-Savart law, an infinitesimally small section of conductor ds through which a current *I* is flowing, generates the following magnetic flux density at the point *r*

$$\mathrm{d}B(r) = \frac{\mu_0}{4\pi} \cdot I \cdot \frac{\mathrm{d}s \times r}{r^3}\,. \tag{1}$$

B: magnetic flux density

$\mu_0 = 4\pi \cdot 10^{-7}\,\frac{\mathrm{Vs}}{\mathrm{Am}}$: permeability of free space

Inside the cylindrical coil, the magnetic flux density is aligned parallel to the axis of the cylinder and is given by the following expression:

$$B = \mu_0 \cdot \frac{N}{L} \cdot I\,. \tag{2}$$

N: number of windings, *L*: length of coil

This applies as long as the length of the coil is much greater than its radius. The magnetic flux density does not therefore depend on the diameter of the coil and is proportional to the density of the windings, i.e. the number of windings per unit length, and the current through the coil.

The experiment involves using an axial teslameter to measure the magnetic flux density inside long coils for currents of up to 20 A. It demonstrates that the flux density does not depend on the coil diameter but is proportional to the current and the winding density. In order to prove the latter, a coil is provided which allows the windings to be moved closer together or farther apart, i.e. varying the number of windings per unit length.

EVALUATION

All the measurements confirm that the magnetic flux density *B* is proportional to the current *I* through the coil.
The flux density is confirmed to be proportional to the windings per unit length as long as the length of the coil is more than three times its radius.

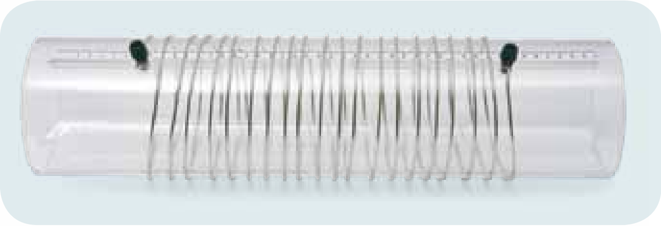


Fig. 1: Coil with variable number of windings per unit length

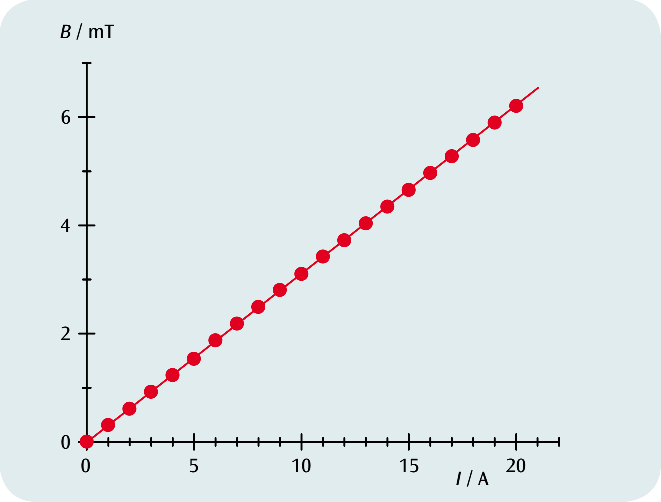


Fig. 2: Magnetic flux density *B* as a function of current *I*

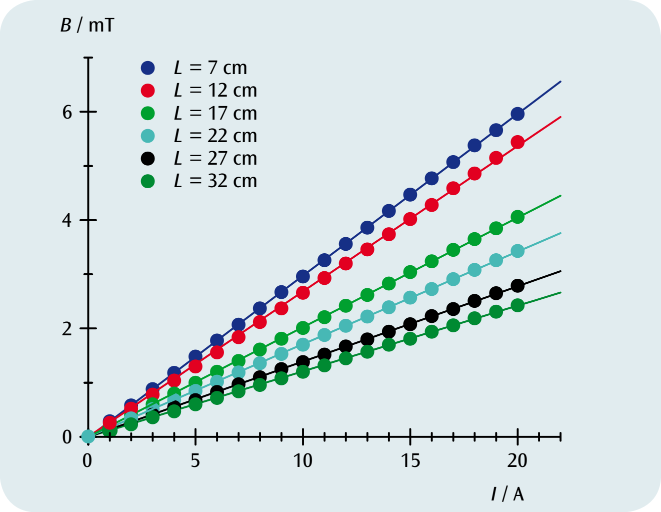


Fig. 3: Magnetic flux density *B* as a function of current *I* using the coil with a variable number of windings per unit length for various lengths of coil *L*

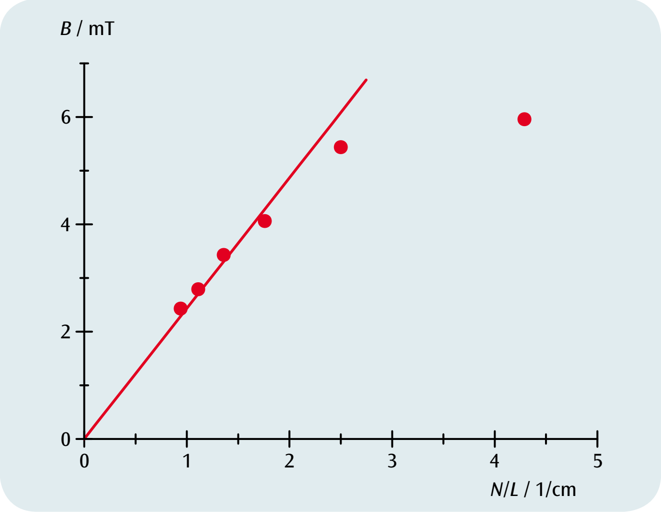


Fig. 4: Magnetic flux density *B* as a function of number of windings per unit length *N*/*L* when *I* = 20 A