Induction - Magnetic Field of Current Carrying Wire

TOPICS AND FILES

E&M Topic

Electromagnetism, magnetic field in a coil

Capstone File

80 Mag Field Coil.cap

EQUIPMENT LIST

Qty	Items	Part Numbers
1	PASCO Interface (for one sensor)	
1	Magnetic Field Sensor	CI-6520A
1	Power Amplifier	CI-6552A
1	Double Rod Clamp	ME-9873
1	Large Rod Base	ME-8735
1	Rod, 45-cm	ME-8736
2	Banana Plug Patch Cord, 4 mm	SE-9750 or SE-9751
2	Alligator Clips (for patch cords)	SE-9756
1	Pulley Mounting Rod	SA-9242
1.2 m	Magnet Wire	
1	Sandpaper, fine grit (sheet)	
1 roll	Tape, sticky	

INTRODUCTION

The purpose of this activity is to measure the magnetic field generated by a current-carrying wire shaped as a coil. Use the power amplifier to create and measure the current in the coil and use the magnetic field sensor to measure the magnetic field strength in the coil. Use *Capstone* to record and display the data. Calculate the permeability of free space (μ_0) based on the size and number of turns in the coil, the measured current, and the measured magnetic field.

BACKGROUND

A current-carrying wire experiences a magnetic force when placed in a magnetic field produced by an external source such as a permanent magnet. A current-carrying wire also produces a magnetic field of its own. Hans Christian Oersted (1777 - 1851) first discovered this effect in 1820 when he observed that a current-carrying wire influenced the orientation of a nearby compass needle. The compass needle aligns itself with the net magnetic field produced by the current and the earth. Oersted's discovery, which linked the motion of electric charges with the creation of a magnetic field, marked the beginning of an important discipline called electromagnetism.

Experimentally, it is found that the magnitude B of the magnetic field produced by a long, straight wire is directly proportional to the current I and inversely proportional to the radial distance r from the wire as shown below.

$$B \propto \frac{I}{r} \tag{1}$$

A proportionality constant converts the expression into an equation that gives the magnitude of the magnetic field around a long, straight wire.

$$B = \frac{\mu_0 I}{2\pi r} \tag{2}$$

The constant "μ_0" is known as the permeability of free space, and its value is shown below.

$$\mu_0 = 4\pi \times 10^{-7} \text{ T } \cdot \text{ m/A} \tag{3}$$

If a current-carrying wire is bent into circular loop, the magnetic field lines around the loop have a pattern similar to that around a bar magnet. At the center of a loop of radius R, the magnetic field is perpendicular to the plane of the loop and has the value shown in the equation below, where I stands for the current in the loop.

$$B = \frac{\mu_0 I}{2R} \tag{4}$$

Often, the loop consists of N turns of wire that are wound so close together that they form a flat coil with a single loop. In this case, the magnetic fields of the individual turns add together to give a net field that is N times greater than that of a single loop. For such a coil the magnetic field at the center depends on the number of loops, the current, and the radius of the loop as shown in the equation below.

$$B = N\frac{\mu_0 I}{2R} \tag{5}$$