Magnetic fields from coils

Physics 225 – Background wiki

Helmholtz coils

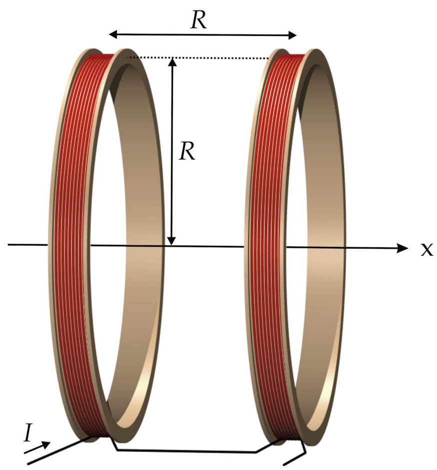

Figure 1: Helmholtz coils. Courtesy of Ansgar Hellwig [CC BY-SA 2.0 de (https://creativecommons.org/licenses/by-sa/2.0/de/deed.en)]

A Helmholtz coil is a pair of identical coils, separated by a distance equal to their radius. When equal currents flow through the wires in the same direction, it creates a fairly uniform magnetic field in the center of the coils.

Magnetic field from a coil of wire

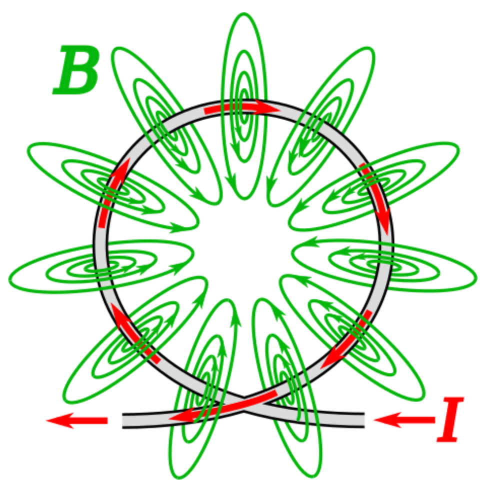

Figure 2: Magnetic field created by a loop of wire. Courtesy of Chetvorno [CC0 (https://commons.wikimedia.org/wiki/File:Magnetic_field_of_loop_3.svg#filelinks)]

A current-carrying wire creates a magnetic field. This is still true when the wire is looped into a coil, as shown in Figure 2. Consider the right hand rule for Figure 2. Use your thumb to point in the direction of the current. Let your fingers curl as if around a wire. The directions of your fingers show how the magnetic field wraps around the wire. If the current is flowing clockwise as shown, the field from all points on the wire point into the page at the center of the loop. This creates a strong field in the center.

Magnetic field from two coils: superposition

Superposition is the principle that overlapping fields add. From superposition, we know that the magnetic field produced by two current-carrying coils is the sum of the two fields produced when only each individual coil carries current. The following figure shows the total vector field that results from two coils with equal currents traveling in the same direction.

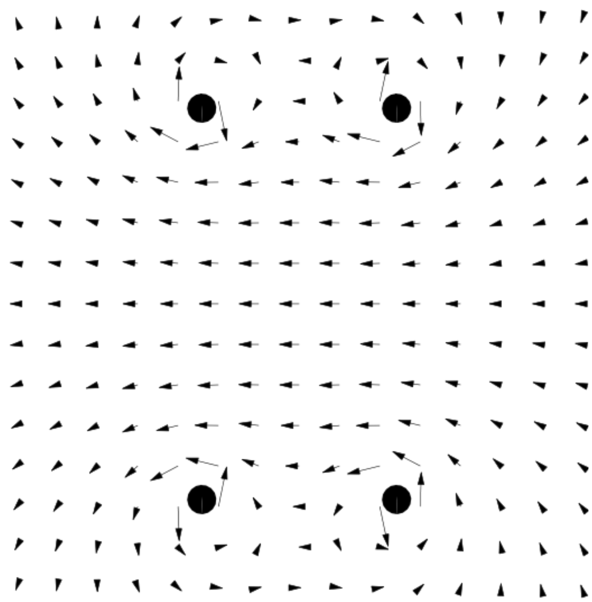

Figure 3: A cross-section of the magnetic field created by two current-carrying coils. Courtesy Tkirkman [Public domain (https://commons.wikimedia.org/wiki/File:B_vector.helmholtz.svg)].

The magnetic field is a vector field--it varies in **magnitude** and **direction** at different positions--so the sum involves vector addition:

$$\vec{B}(\vec{r}) = \vec{B}_1(\vec{r}) + \vec{B}_2(\vec{r}) \qquad \text{(Equation 1)}$$

where

- $\vec{B}(\vec{r})$ is the magnetic field at a position $\vec{r}$ when both sources are "on"
- $\vec{B}_1(\vec{r})$ is the field when only the first source is "on"
- $\vec{B}_2(\vec{r})$ is the field when only the second source is "on"