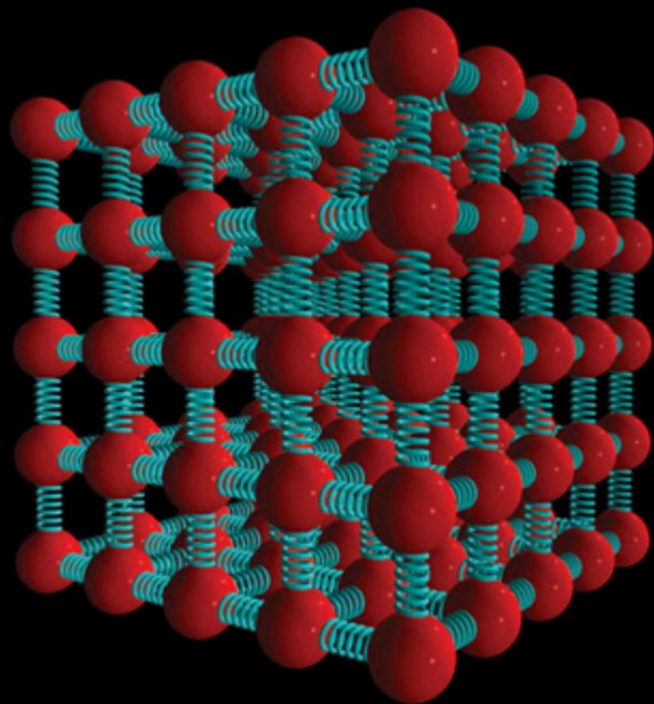
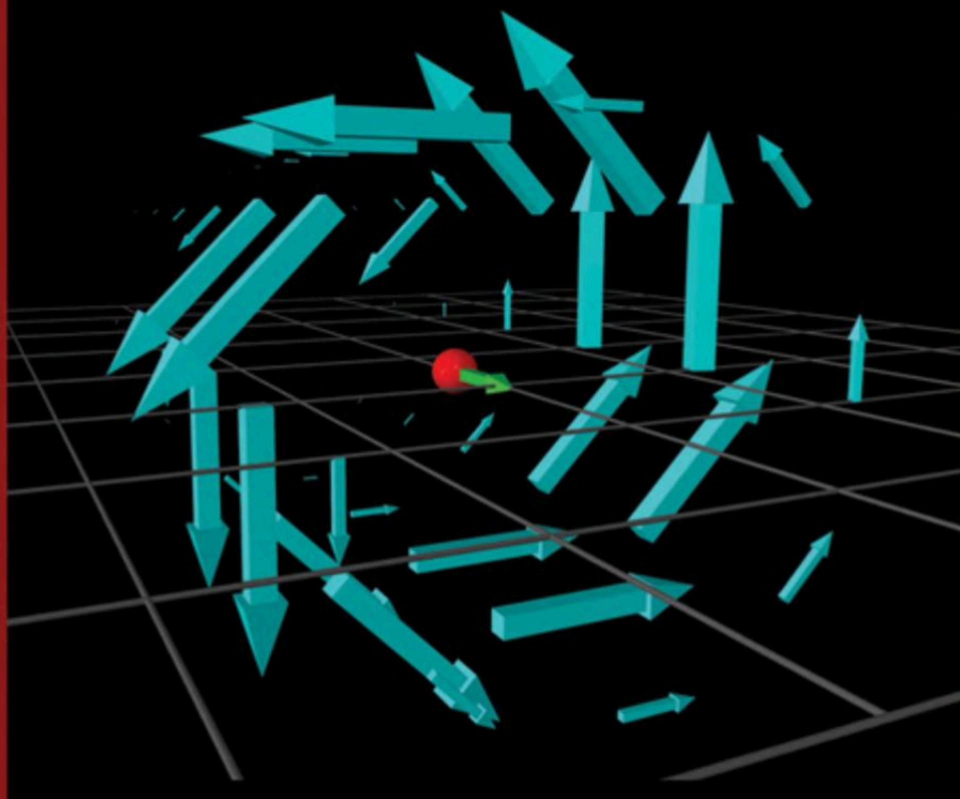
CHABAY • SHERWOOD



MATTER & INTERACTIONS

3rd EDITION



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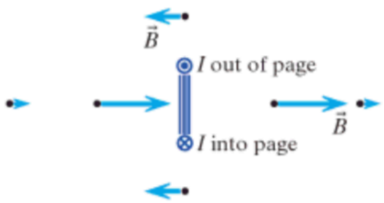

Figure 18.32 The magnetic field above and below the coil points in the opposite direction to the field along the axis.

Far above the coil in Figure 18.31, the closer upper part of the coil contributes a larger magnetic field to the left than does the slightly farther away lower part of the coil to the right. A detailed calculation shows that this is also true a short distance above the coil (Figure 18.32). Compare the pattern of magnetic field with the pattern of *electric* field around an electric dipole.

Magnetic Field at Other Locations Outside the Loop

The magnetic field at other locations outside the loop is more difficult to calculate analytically, but the magnetic field has a characteristic dipole pattern as shown in Figure 18.33, which is the result of a computer calculation that added up all the contributions of many short sections of the loop.

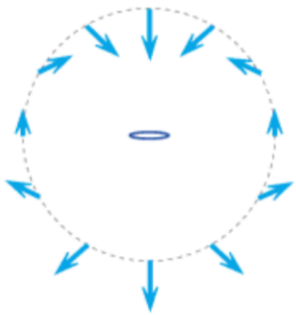

Figure 18.33 The magnetic field of a current loop (which lies in the xz plane, viewed edge-on), at locations outside the loop, in a plane containing the axis of the loop.

A Special Right-Hand Rule for Current Loops

There is another "right-hand rule" that is often used to get the direction of the magnetic field along the axis of a loop. Let the fingers of your right hand curl around in the direction of the conventional current, and your thumb will point in the direction of the magnetic field at any location on the axis.

> **QUESTION** Try using this right-hand rule to determine the direction of the magnetic field at the indicated observation location in Figure 18.34.

You should find that the magnetic field points down. This right-hand rule should of course give the same result as applying the more general right-hand rule to the cross product $\Delta\vec{l} \times \hat{r}$ and adding up the contributions of the various parts of the loop, as called for by the Biot–Savart law.

> **QUESTION** On the diagram, consider $\Delta\vec{l} \times \hat{r}$ for two short pieces of the loop, on opposite sides of the loop. Show that the two pieces together contribute a magnetic field in the downward direction above the loop.

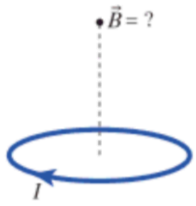

Figure 18.34 Curl the fingers of your right hand in the direction of the conventional current, and your thumb will point in the direction of the magnetic field.

18.9 MAGNETIC DIPOLE MOMENT

Recall the formula for the electric field along the axis of an electric dipole, at a distance r far from the dipole:

$$E_{\text{axis}} \approx \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$$

where the "electric dipole moment" $p = qs$. Similarly, in the formula for the magnetic field along the axis of a current-carrying coil at a distance r far from the coil, we can write this:

$$B_{\text{axis}} \approx \frac{\mu_0}{4\pi}\frac{2\mu}{r^3}$$

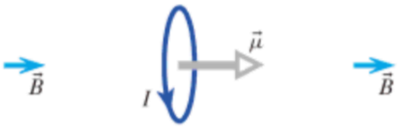

Figure 18.35 The magnetic dipole moment $\vec{\mu}$ is considered to be a vector pointing in the direction of the magnetic field along the axis.

where the "magnetic dipole moment" $\mu = IA$. (If there are N loops, $\mu = NIA$.) Here A is the area of the loop (πR^2 for circular loops). This formula for magnetic field is approximately valid even if the loop is not circular. The magnetic dipole moment $\vec{\mu}$ is considered to be a vector pointing in the direction of the magnetic field along the axis (Figure 18.35). This means that the direction of the magnetic dipole moment can be obtained by curling the fingers of your right hand in the direction of the conventional current, and your thumb points in the direction of the magnetic dipole moment.