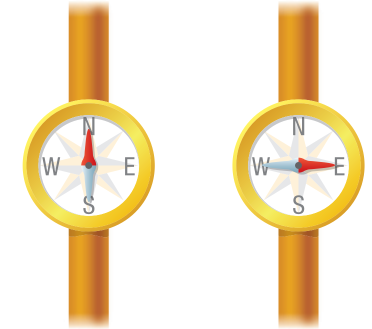
Oersted's Discovery

Is there a link between electricity and magnetism? Charged particles behave in a similar way to magnetic poles. Like charges (positive and positive or negative and negative) repel each other and unlike charges (positive and negative) attract each other. In 1819, Danish physicist Hans Christian Oersted was the first scientist to successfully connect electricity and magnetism. We have since found out that the electromagnetic force is one of the four fundamental forces of nature.



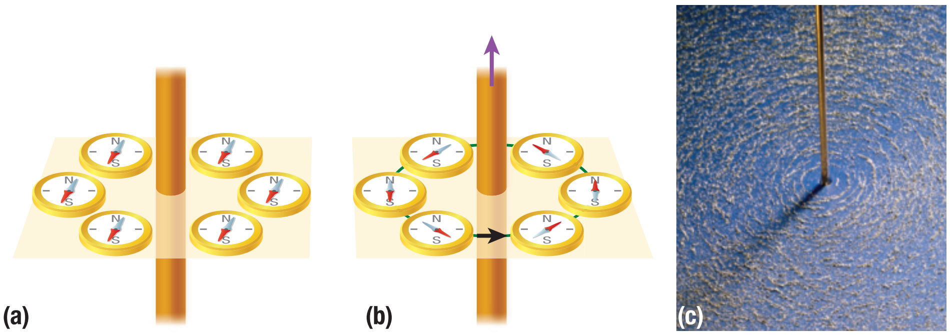
(a) **(b)**

Figure 1 (a) Compass direction with no electric current. The compass and the wire are aligned with Earth's magnetic north pole. (b) Compass direction with an electric current in the wire

Oersted's Experiment

Before Oersted, many physicists had hypothesized that magnetic fields could be created by an electric current in a wire. Oersted hypothesized that the current would produce a magnetic field that radiated away from the wire. He tested his hypothesis with a compass held near a conducting wire in an electric circuit. He placed the compass so that it aligned with the wire, which, in turn, was aligned with Earth's magnetic field (**Figure 1(a)**). When an electric current was present in the wire, the compass needle was deflected perpendicular to the wire (**Figure 1(b)**). When the current in the circuit was switched off, the compass needle went back to its original position. When the electric current was reversed, the compass needle was deflected in the opposite direction.

Further investigation led to an understanding of the shape of the magnetic field around a conductor. The magnetic field surrounds the conductor in the shape of concentric circles (**Figure 2**). The direction of the magnetic field depends on the direction of the current. Reversing the direction of the electric current also reverses the direction of the magnetic field. It was also noted that the strength of the magnetic field gets weaker farther away from the conducting wire.



(a) **(b)** **(c)**

Figure 2 (a) When no electric current is present in the wire, the compasses point toward Earth's magnetic north pole. (b) When an electric current is directed up the wire, the compasses follow the circular magnetic field. (c) Iron filings around a copper wire with an electric current

In Oersted's time, the prevailing theory assumed that electric current was directed from the positive terminal to the negative terminal of a power source. Many of the rules of electromagnetism were therefore developed using the conventional current model. Hence, the magnetic field shown in Figure 2(b) is for a conventional current moving from the bottom to the top of the wire. It is important to understand that the magnetic field around the wire is independent of whether you use the conventional current model or the electron flow model.

Oersted developed a principle that describes the magnetic field around a current-carrying conductor. **Oersted's principle** states that a charge moving through a straight conductor produces a circular magnetic field around the conductor.

Oersted's principle whenever a charge moves through a straight conductor, a circular magnetic field is created around the conductor

Applying Oersted's Principle

right-hand rule for a straight conductor if you hold a straight conductor in your right hand with your right thumb pointing in the direction of the conventional current, your curled fingers will point in the direction of the magnetic field lines

A learning tool was developed to help determine the direction of the magnetic field around a straight current-carrying conductor. The **right-hand rule for a straight conductor** states that if a straight conductor is held in your right hand with your right thumb pointing in the direction of the conventional current, your curled fingers will point in the direction of the magnetic field lines surrounding the conductor (**Figure 3**).

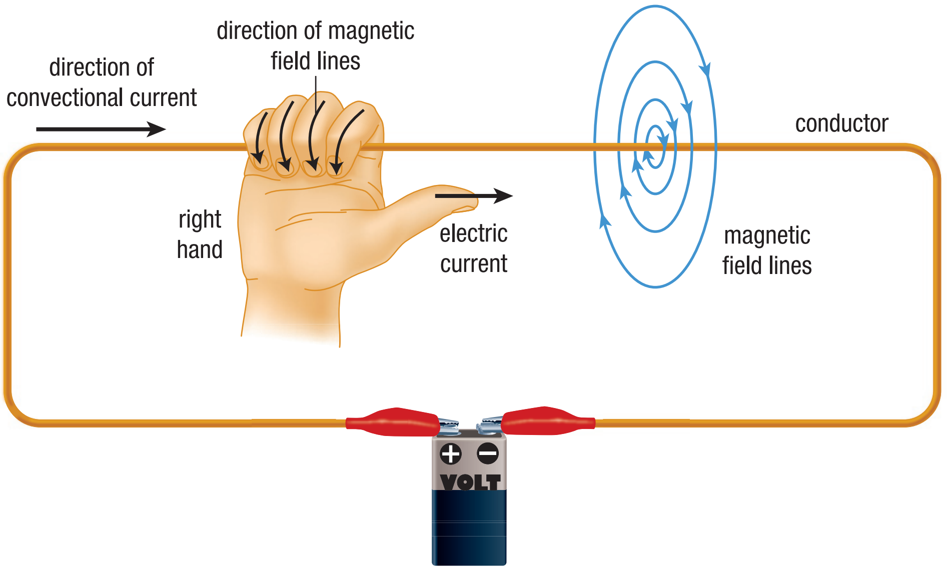


Figure 3 The right-hand rule for a straight conductor

LEARNING TIP

Magnetic Field Direction
Regardless of whether you use the conventional current direction or the electron flow direction to determine which way the current travels, the magnetic field around a current-carrying wire is the same.

Conventional Current versus Electron Flow

You may wonder why conventional current is used when science has demonstrated that the electron flow model is accurate for conducting wires in circuits. Physicists have chosen to use conventional current because you would expect charge to flow from where there is an excess of charge to where there is a deficit of charge. Recall from Section 11.4 that Benjamin Franklin chose positive to represent excess charge. As a result, conventional current models the flow of charges from positive to negative. With conventional current, you use your right hand to determine the direction of the magnetic field.

If you want to use the electron flow model instead, then you must use your left hand. Imagine a corresponding left-hand rule for a straight conductor. It is similar, except your left thumb follows the direction of electron flow. The fingers of your left hand still curl in the direction of the magnetic field lines. The direction of the magnetic field is the same whether you use the right-hand rule or the left-hand rule. Try using the left-hand rule as shown in **Figure 4** to confirm this.

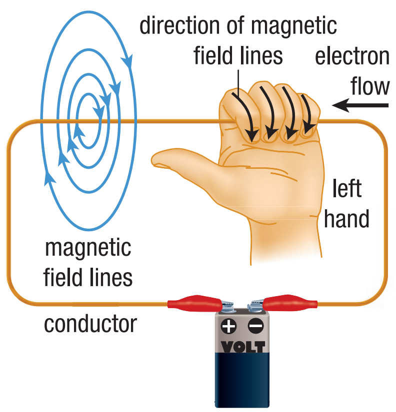


Figure 4 The left-hand rule for electron flow in a straight wire, showing the direction of the magnetic field lines. Notice that the direction of the magnetic field lines is the same in Figure 3 and Figure 4.

Representing Currents and Magnetic Fields

There are many different ways to represent a wire with a conventional current present in it. You can draw the wire in a three-dimensional way, as in Figure 3 and Figure 4. You can also draw the wire as a cross-section. To keep the drawing simple, the current can go into the page or out of the page. To represent a conventional current going into the page we use an X (**Figure 5(a)**), and to represent a conventional current coming out of the page we use a dot (**Figure 5(b)**). This model is based on an arrow. Imagine an arrow travelling away from you—you would see the tail in the shape of an X. If the arrow were travelling toward you, you would see the point of the arrow in the shape of a dot. Note how the concentric circles representing the magnetic field are farther apart as you move away from the wire in Figure 5. The greater spacing represents the weaker strength of the magnetic field as you move away from the wire.

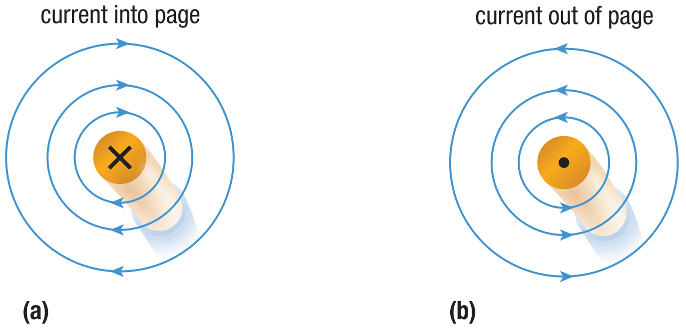


Figure 5 (a) The X represents current in a conductor moving into the page, and the blue concentric circles show the direction of the magnetic field. (b) The dot represents current in a conductor moving out of the page, and the blue concentric circles show the direction of the magnetic field.

Another method for showing the direction of the magnetic field is to use a compass. If you place the compass on top of the wire, the wire will be obscured by the compass. If you place the compass below the wire, the wire will obscure the compass (**Figure 6**).

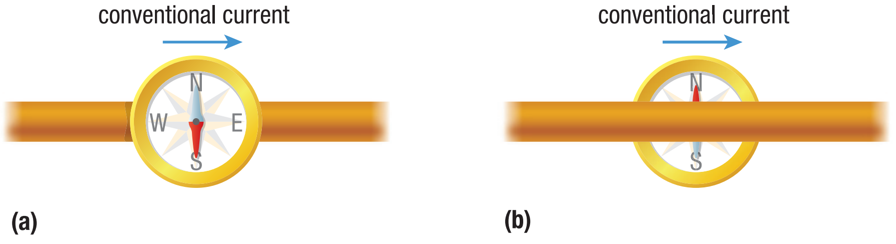


Figure 6 (a) The compass is on top of the wire with the magnetic field pointing downward. (b) The compass is underneath the wire with the magnetic field pointing upward.

Using the right-hand rule, your thumb points to the right. Imagine grabbing the wire; use your pencil as a substitute. Notice that your fingers are pointing down if they are in front of the pencil and up if they are behind the pencil.

Implications of Oersted's Discovery

Oersted's discovery forever changed the world, leading to new kinds of technologies, such as motors and generators. He demonstrated that we could use electricity to produce magnetism. Controlling magnetism means that we can turn it on and off and change its strength by increasing or decreasing the current. We can also control the direction of the magnetic field by changing the direction of the electric current.

12.2 Summary

- Hans Christian Oersted discovered that an electric current in a conductor produces a magnetic field around the conductor.
- Oersted's principle states that a charge moving through a straight conductor produces a circular magnetic field around the conductor.
- The right-hand rule for a straight conductor states that if a straight conductor is held in your right hand with your right thumb pointing in the direction of the conventional current, your curled fingers will point in the direction of the magnetic field lines.
- Oersted's discovery can be used to produce magnetic fields with properties that can be controlled.

12.2 Questions

1. Copy each diagram in **Figure 7** into your notebook and draw the magnetic field. K/U C

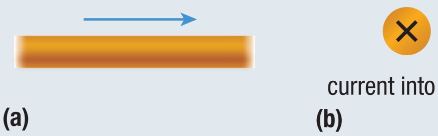


Figure 7

2. Copy each diagram in **Figure 8** into your notebook and label the direction of the conventional current. K/U C

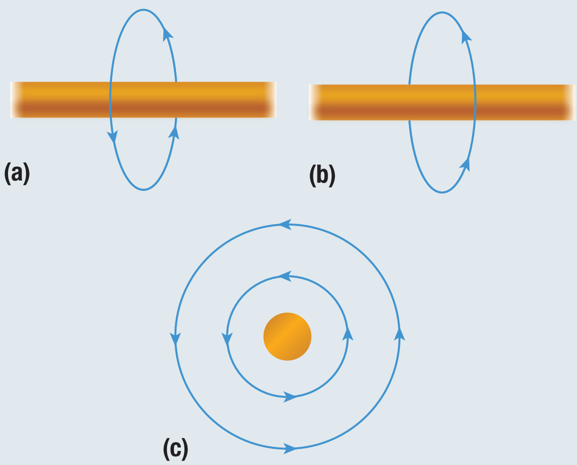


Figure 8

3. A student draws a diagram showing what the magnetic field around a current-carrying conductor looks like. The student draws concentric circles that are equally spaced around the conductor. Explain why the student's diagram is inaccurate. T/I

4. Explain how the diagram in **Figure 9** would change if you were to use the left-hand rule or the right-hand rule. K/U C

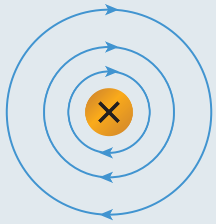


Figure 9

5. You are driving east in your car. Your car is equipped with a magnetic compass display in your rear-view mirror. You happen to drive underneath an electric wire that is labelled high current. You notice that your compass immediately displays north. In which direction is the conventional current flowing in the wire? T/I

6. You use a current-carrying straight conductor to produce a magnetic field. Which three properties of the magnetic field can you control? K/U

7. Which way will the compass point in the diagrams in **Figure 10**? K/U T/I C

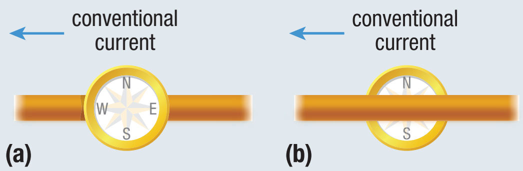


Figure 10