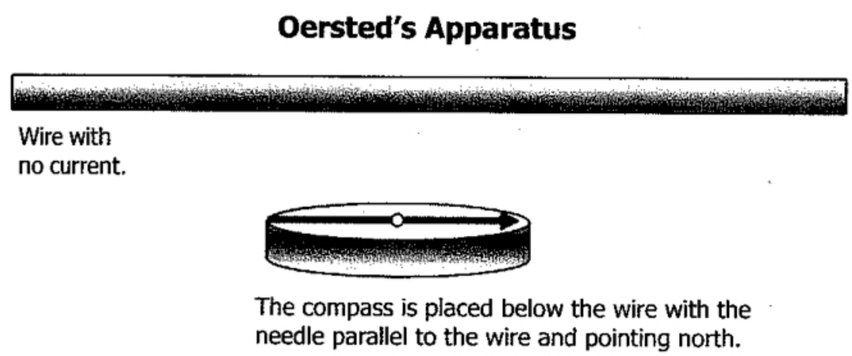
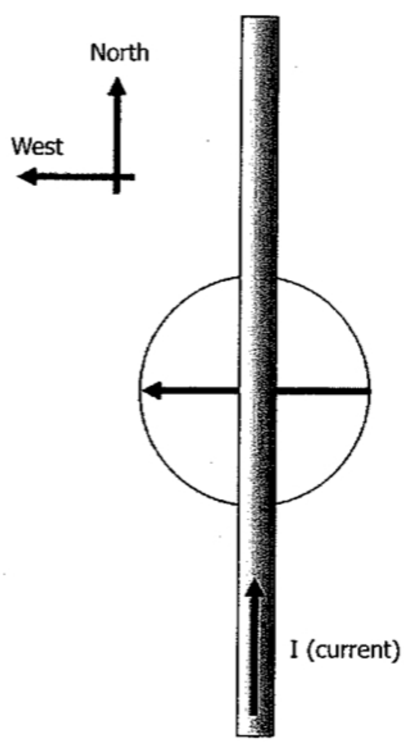
Electromagnetism

In 1820, Hans Christian Oersted made an accidental, but very important discovery. By chance, he had a wire connected to a battery that passed above and nearly parallel to a compass.



When an electric current was passed through the wire, the needle of the compass swung around to be almost perpendicular to the wire, as if gripped by a powerful magnet.

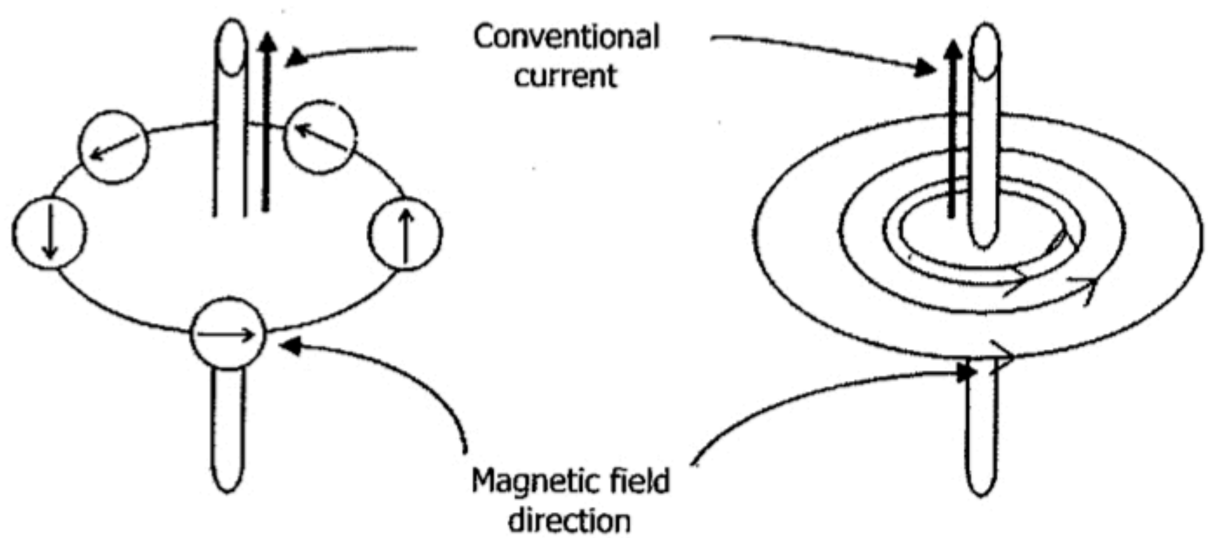


From this lucky observation, Oersted was able to determine the basic **principle of electromagnetism**:

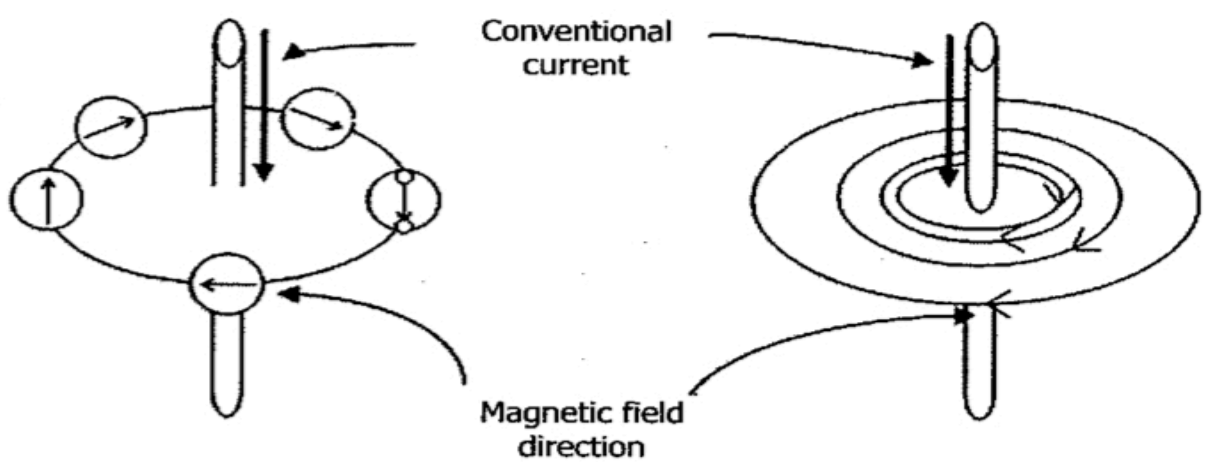
Electric currents produce a magnetic field.

Later that year, Ampere showed that the magnetic field in the vicinity of a current carrying wire was a series of circles, all centered on the wire.

Magnetic Field around a Straight Wire



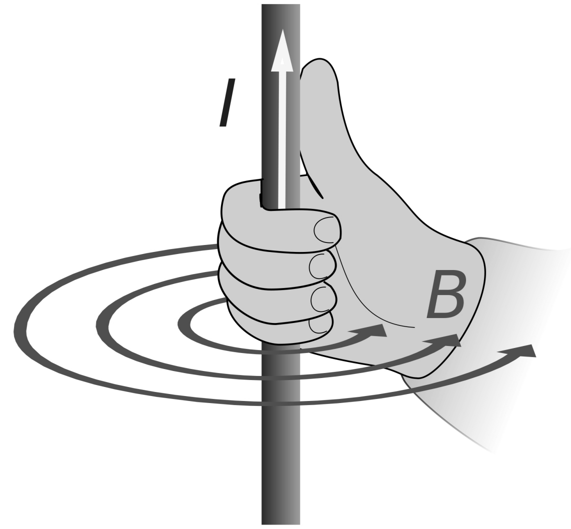
Notice that, in the case of an upward directed current, the magnetic field lines circle the wire in a counterclockwise direction. If the current is reversed, the magnetic field lines will also reverse direction.



The direction of the field lines around a current-carrying wire can be determined using something called the first right-hand rule.

Right-Hand Rule #1

Grasp the wire in your right fist so that your thumb is extended and points in the direction of the current. Your fingers will then curl around the wire in the same direction as the magnetic field lines.

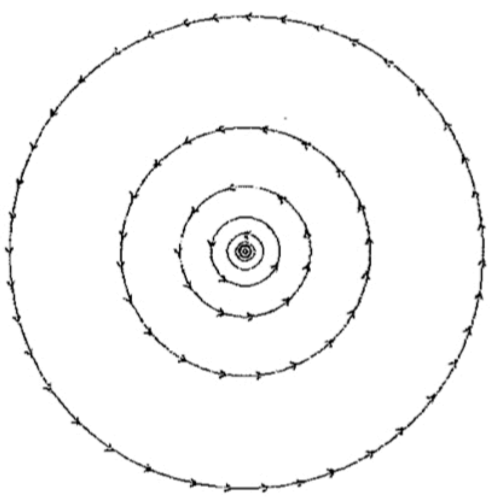


Drawing Magnetic Fields

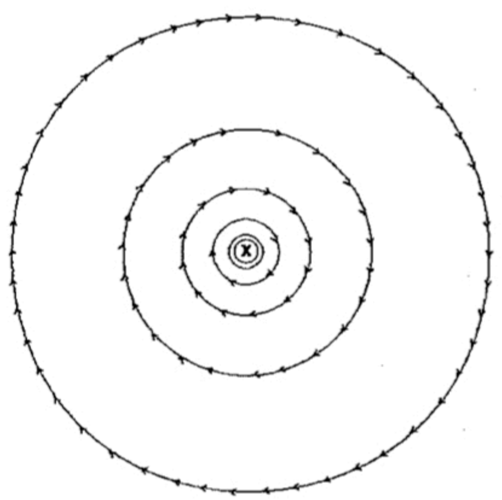
Magnetic fields can be difficult to draw because they occur in three dimensions. To simplify our diagrams, we typically draw the current in the wire as either traveling into the page or out of the page. The wire is represented by a circle. If the current is flowing out of the page, we put a dot in the middle of the circle. If the current is traveling into the page, we put an X.

The first right hand rule is still used to determine direction.

Magnetic Field around a Wire Carrying a Current **OUT** of the Page

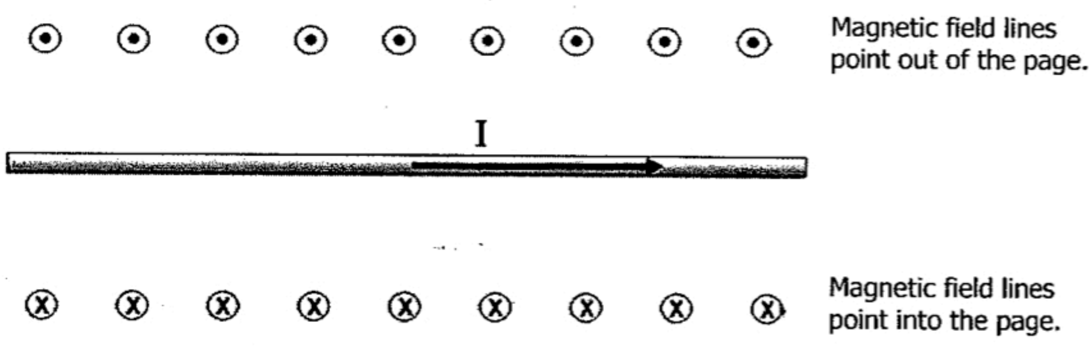


Magnetic Field around a Wire Carrying a Current **INTO** the Page

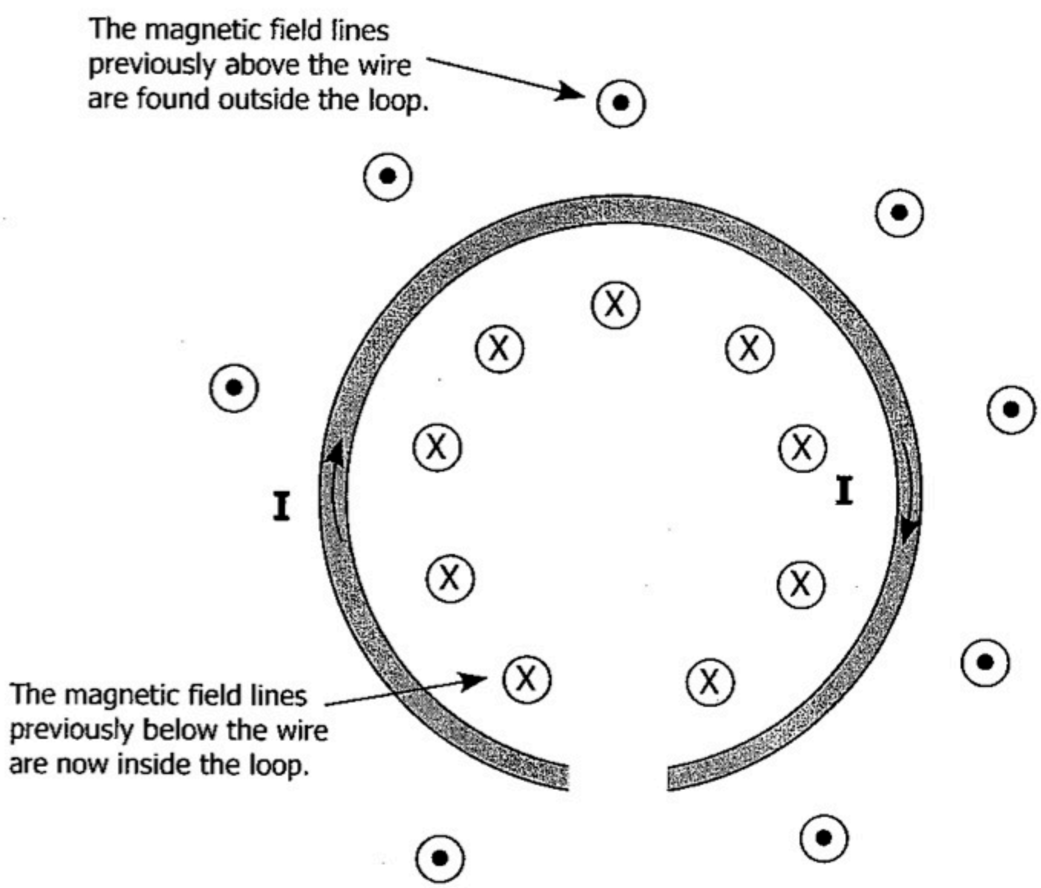


Magnetic Field of a Loop

The diagram below shows the field around a straight wire, drawn in cross-section.

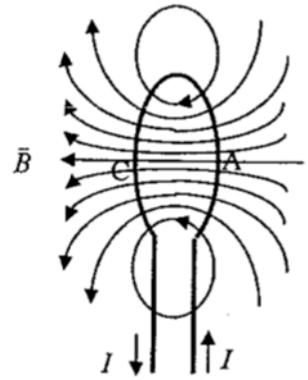


When a straight wire is bent into the shape of a circular loop, its magnetic field will appear as shown in the following diagram.



You can see that the magnetic field lines become concentrated inside the loop and spread out outside the loop. Thus, the field inside the loop is considerably stronger than the field outside the loop.

The diagram to the right shows a different perspective on a current carrying loop. As you look at the diagram, imagine that side A is closer to you and side C is farther from you. As the current moves through the loop, the magnetic field passes through the inside of the loop in the direction shown.



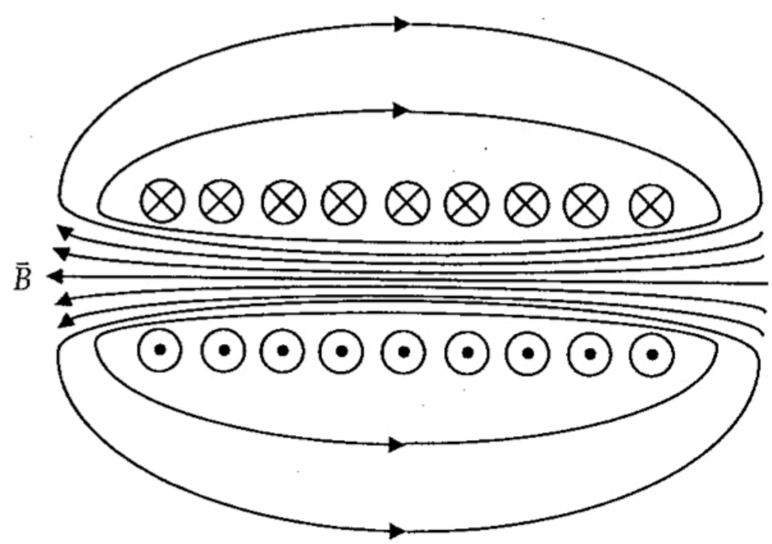
To determine the direction of the magnetic field of a current loop, we can use the second right-hand rule.

Right-Hand Rule #2

If the fingers of the right hand are "wrapped around" the loop in the same direction that the current flows, then the thumb (when extended) will point in the direction of the magnetic field lines inside the loop.

Magnetic Field of a Solenoid

If a long wire is wound into a spiral with many loop, we have what is called a **solenoid**. The magnetic field of a solenoid is the sum of the magnetic fields of all of its loops. As a result, the field inside the coil can be very strong, consisting of field lines that are nearly straight and very close together, as shown.



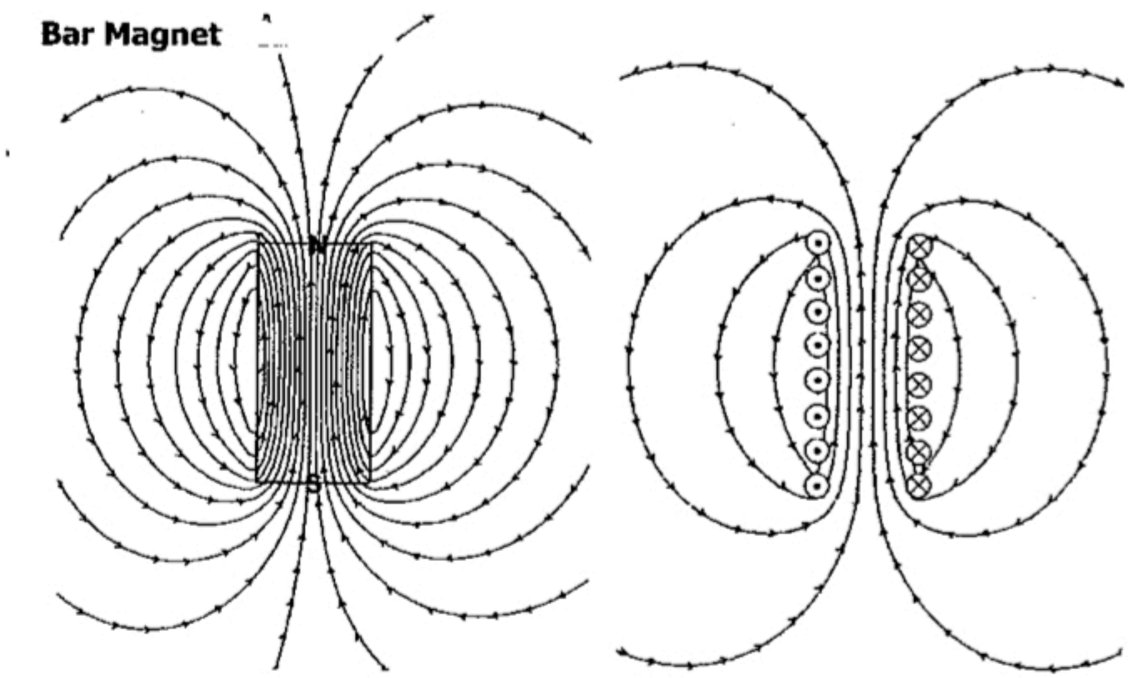
The current moves into the page along the top edge of the solenoid and out of the page along the bottom edge. The magnetic field points to the left inside this solenoid.

The right-hand rule for loops can be applied to a solenoid to determine the direction of the magnetic field. If you grasp the solenoid so that your fingers curl in the direction that the current flows around the loops, your extended thumb will point in the direction of the field lines inside the solenoid.

It is important to note that a solenoid has a magnetic field that is very similar to that of a bar magnet. In fact, a solenoid acts in many ways like a bar magnet, with the exception that the magnetic field of a solenoid can be turned off and on by turning the current off and on. This property of solenoids led quite naturally to the creation of the electromagnet.

The Electromagnet

A solenoid is an example of an electromagnet. When carrying a current, it will produce a field much like a bar magnet.



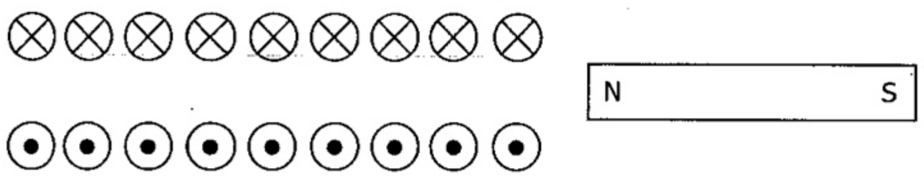
The end of the solenoid where the magnetic field is coming out would be the north pole. The end where the magnetic field is entering would be the south pole.

The strength of an electromagnet can be affected by several factors:

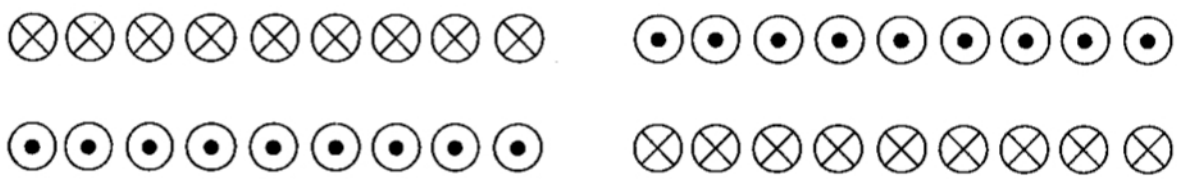
- If the number of coils (turns of wire) in the solenoid is increased, the magnetic field will also increase.
- If the amount of current flowing through the coil is increased, the magnetic field will also increase.
- If a ferromagnetic material, like iron, is placed in the center of the solenoid, the strength of the magnetic field will be dramatically increased.

Magnetic Fields Worksheet

1. A solenoid is shown below near a bar magnet. Draw the magnetic field lines for the solenoid. Will the solenoid and the bar magnet attract or repel each other?



2. Two solenoids are placed side by side as shown below. Will the solenoids attract or repel each other?



3. The following are ways in which the operation of an electromagnet can be changed. Indicate whether the change will produce a stronger magnetic field or a weaker field.

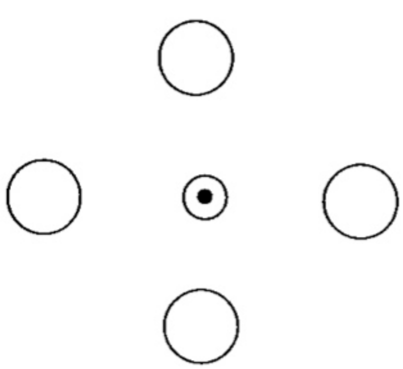
   a) Removing the iron core from the solenoid.

   b) Increasing the number of coils of wire.

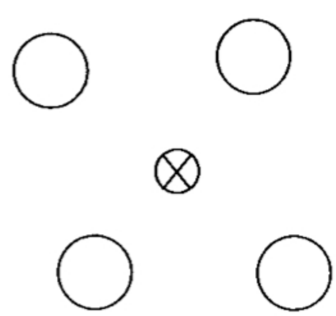
   c) Decreasing the amount of current flowing through the solenoid.

4. A wire is aligned so that it is straight and comes out of the page. The wire is at the center of the diagram and each circle around the wire represents a compass. Indicate the direction of the compass needle in each circle.

a)

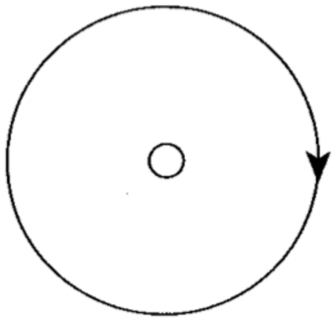


b)



5. Each empty circle represents a conductor surrounded by a magnetic field. State whether a dot of an "X" should be placed in each circle.

a)



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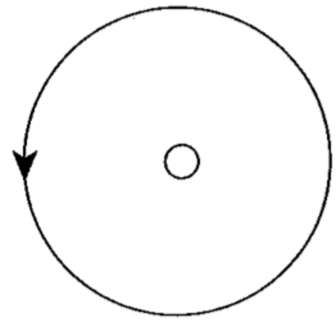
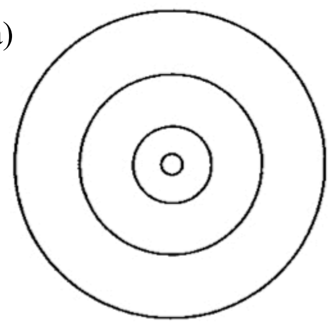
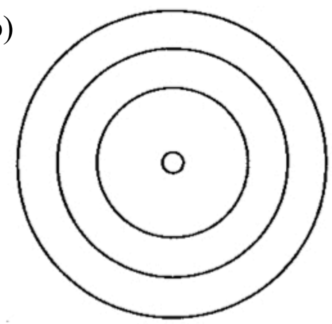


6. Choose the diagram that best represents the magnetic field around a straight current-carrying wire. Explain your choice.

a)



b)



c)