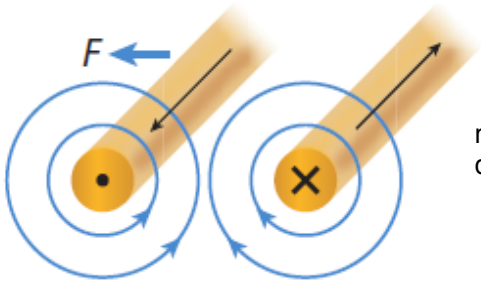
Section 12.4 - Putting Magnetic Fields to Good Use - Solenoid

Two magnetic fields can interact with each other to cause a force. The force can either be attractive or repulsive, depending on the directions of the two interacting fields. If two field lines point in the same direction, a repulsion force is applied. Conversely, if two field lines point in opposite directions, an attractive force is applied.



magnetic field lines point in the same direction - repulsive force

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Coiled Conductors - Building Upon a Simple Idea

Remember, we are using the Conventional Flow (pos to neg) approach.

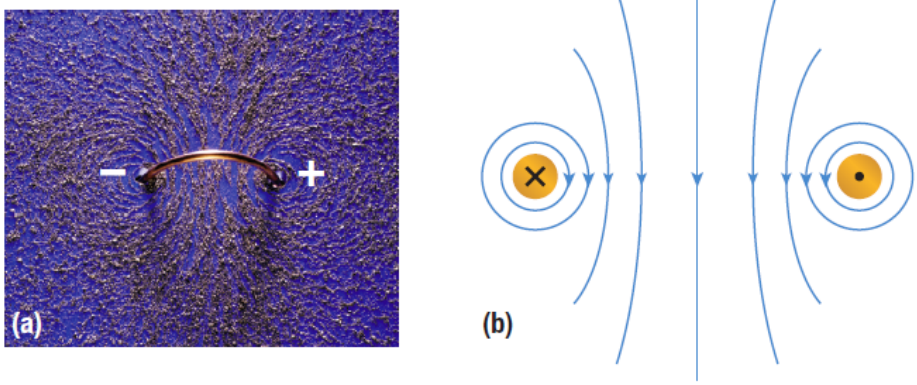

Figure 2 The magnetic field around a loop of wire (a) using iron filings and (b) showing the magnetic field lines

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Now imagine winding the conductor into a coil containing several loops. Another name for a coiled conductor is a solenoid. The magnetic field around a solenoid has a shape similar to that of a bar magnet. To understand why this is so, look closely at **Figure 3(a)**. The convention of dots and X's is used to show the direction of conventional current. The circular magnetic fields around each dot and X combine to form an overall magnetic field that is a close approximation to the magnetic field of a bar magnet (**Figure 3(b)**). The magnetic field is strongest at the poles or ends of the coils and is weakest at the sides.

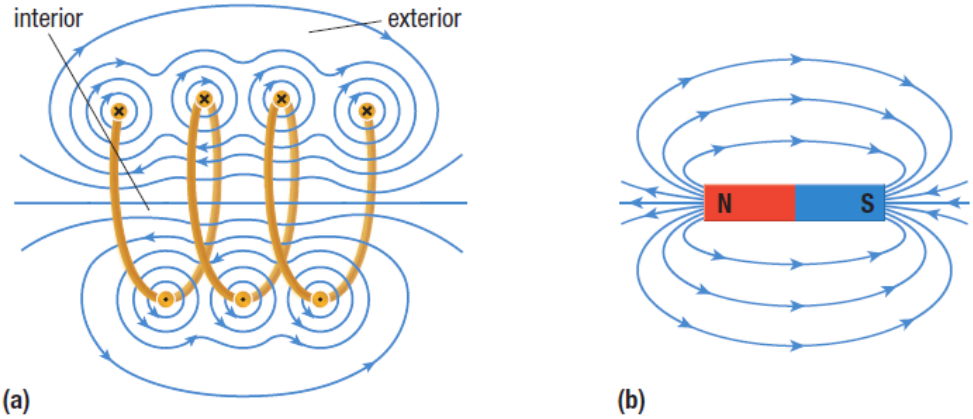

Figure 3 The magnetic field lines around (a) a solenoid and around (b) a bar magnet

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An electromagnet is a device that has a magnetic field produced by an electric current. The benefit of the electromagnet is that it can be switched on and off . The strength of the electromagnet can be increased by increasing the number of loops in the coil, increasing the current, or introducing a core made from a material that is quickly magnetized. Soft iron is such a material, and it can be just as quickly de-magnetized when the current is switched off . A core material like soft iron concentrates the magnetic field. To make a very powerful magnet, we include all three factors. The most powerful electromagnets have several thousand loops of wire, work with large currents, and have a soft -iron core.

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Right-Hand Rule for a Solenoid

There is another right-hand rule to help you determine the direction of the magnetic field or the direction of the conventional current. The **right-hand rule for a solenoid** states that if the fingers of your right hand wrap around a coil in the direction of the conventional current, your thumb will point in the direction of the north magnetic pole of the coil (**Figure 4**).

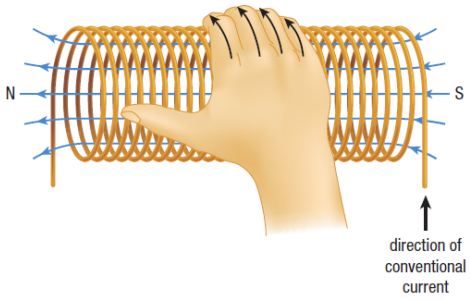

Figure 4 The right-hand rule for a solenoid

Applications of Solenoids

A solenoid has many uses because it operates like a bar magnet, but it can be switched on and off. So a solenoid can be used to turn things on and off, to pick up things and to then let go, or to cause motion and then reverse the motion. Solenoids are used in many devices, such as audio speakers, electric bells, and cars.

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Solenoids in Subwoofers

A subwoofer is a speaker that produces only low-frequency or deep bass sounds. Subwoofer speakers have become popular because they can produce the low-frequency sound effects in surround-sound systems. To produce sound you have to create longitudinal vibrations in the air, with compressions and rarefactions. The subwoofer has a cone made from paper or plastic that quickly moves outward to cause a compression and then quickly moves inward to cause a rarefaction. To move the cone, a permanent circular magnet surrounds a solenoid called the voice coil. The voice coil is connected to the cone. Current is directed through the voice coil by an amplifier, which produces a magnetic field that repels the voice coil and the cone away from the magnet. The amplifier then reverses the direction of the current and produces a magnetic field that attracts the voice coil and the cone toward the magnet. This process repeats continually, producing compressions and rarefactions to create sound (**Figure 5**).

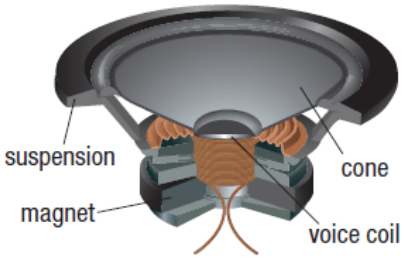

Figure 5 A cross-section of a subwoofer

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Solenoids in Electric Bells

The school bell signals the beginning or the end of a period. Many schools still have bells based on a solenoid. The design of the electric bell allows it to be rung continuously for as long as needed. **Figure 6** shows the operational parts of an electric bell. When the switch is closed, current is directed to the solenoids. The solenoids produce a magnetic field that is amplified by the soft-iron cores. The soft-iron armature is attracted to the core and the bell rings once. Now the armature pulls away from the contact, so the circuit is interrupted. Since the armature is on a spring, it springs back and makes contact, completing the circuit once more. The process then repeats as long as the switch is closed.

Solenoids in Cars

There are many places in cars where a magnetic field can be used to perform a task. In the starter, a solenoid is used as a switch that completes a circuit to initiate the starter motor, which starts the car. Once the car has started, the solenoid is used to switch off the starter motor because the engine is running. In the door-unlocking mechanism, a solenoid is again used as a switch that completes a circuit to cause an actuator (a device that exerts a force) to unlock the car. Even in a car's automatic transmission, a solenoid is used to initiate gear shifts.

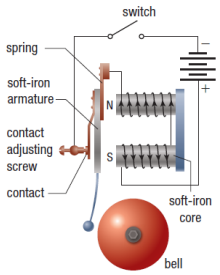

Figure 6 An electric bell

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12.4 Summary

- Two parallel wires placed close to one another with opposing currents will repel one another.
- A current in a loop of wire will produce circular magnetic fields around the wire and a straight-line field inside the centre of the loop.
- A current in a coil of wire, or solenoid, will produce a magnetic field that is similar to that of a bar magnet.
- The strength of a solenoid's magnetic field can be increased by increasing the number of loops, increasing the amount of electric current, including a soft-iron core, or any combination of these.
- The right-hand rule for a solenoid is as follows: the fingers of your right hand wrap around the coil in the direction of the conventional current, while your thumb points in the direction of the north magnetic pole of the coil.
- Solenoids are used in many technologies, including subwoofers, electric bells, car starter motors, and car-door locking and unlocking mechanisms.

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12.4 Questions

1. Copy the diagrams in **Figure 7** into your notebook, and draw the direction of the conventional current or the magnetic field lines. Also indicate the location of the north and south poles where appropriate. K/U C

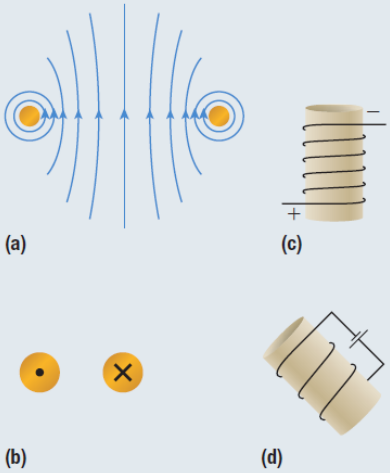

Figure 7

5. An electromagnetic relay is a device used to trigger another circuit. An illustration of it is shown in **Figure 9**. K/U C
   (a) Describe how it works.
   (b) Describe a situation where an electromagnetic relay may be used.

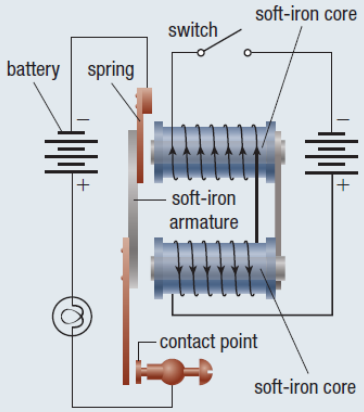

Figure 9

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