Summary

THE BIG IDEA **A moving electric charge is surrounded by a magnetic field.**

36.1 Magnetic Poles

Like poles repel; opposite poles attract.

- Magnets can both attract and repel without touching. The strength of the interaction between two magnets depends on the distance between them.
- Regions called **magnetic poles** produce magnetic forces.
- If you suspend a bar magnet from its center by a piece of string, it will act as a compass. The end that points northward is called the *north pole*. The end that points south is called the *south pole*. All magnets have a north and a south pole.
- If the north pole of one magnet is brought near the north pole of another magnet, they repel. The same is true of a south pole near a south pole. If opposite poles are brought together, however, attraction occurs.
- A north magnetic pole never exists without the presence of a south pole, and vice versa. If you break a bar magnet, each piece still behaves as a complete magnet.

36.2 Magnetic Fields

The direction of the magnetic field outside a magnet is from the north to the south pole.

- The space around a magnet, in which a magnetic force is exerted, is filled with a **magnetic field.** The shape of the field is revealed by *magnetic field lines* that spread out from the north pole, curve around the magnet, and return to the south pole.
- Where the magnetic field lines are closer together, the field strength is greater than where the lines are farther apart.

36.3 The Nature of a Magnetic Field

A magnetic field is produced by the motion of electric charge.

- Just as an electric charge is surrounded by an electric field, a moving electric charge is surrounded by a magnetic field.
- Both the orbital motion and the spinning motion of every electron in an atom produce magnetic fields.
- Every spinning electron is a tiny magnet. Multiple electrons spinning in the same direction make a stronger magnet, but electrons spinning in opposite directions work against one another. Their magnetic fields cancel. This is why most substances are not magnets.

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36.4 Magnetic Domains

Permanent magnets are made by simply placing pieces of iron or certain iron alloys in strong magnetic fields.

- The magnetic fields of individual atoms are sometimes so strong that interactions among adjacent atoms cause large clusters of them to line up. These clusters of aligned atoms are called **magnetic domains.**
- The difference between ordinary iron and an iron magnet is the alignment of domains.
- Iron can be magnetized by placing it in a strong magnetic field or by stroking it with a magnet.

36.5 Electric Currents and Magnetic Fields

An electric current produces a magnetic field.

- If you arrange magnetic compasses around a current-carrying wire, the compasses will align with the magnetic field around the wire.
- A current-carrying coil of wire with many loops is an **electromagnet.** A piece of iron inside the coil increases the magnetic field intensity.

36.6 Magnetic Forces on Moving Charged Particles

A moving charge is deflected when it crosses magnetic field lines but not when it travels parallel to the field lines.

- A charged particle at rest will not interact with a static magnetic field. However, if the charged particle *moves* in a magnetic field, the particle experiences a deflecting force. The direction of the deflecting force is always perpendicular to both the magnetic field lines and the velocity of the charged particle.
- Examples of magnetic forces acting on moving charged particles include the deflection of electrons in TV tubes and the deflection of cosmic radiation by Earth's magnetic field.

36.7 Magnetic Forces on Current-Carrying Wires

Since a charged particle moving through a magnetic field experiences a deflecting force, a current of charged particles moving through a magnetic field also experiences a deflecting force.

- A current-carrying wire experiences a force in a magnetic field. If the direction of current in the wire is reversed, the deflecting force acts in the opposite direction. The force is maximum when the current is perpendicular to the magnetic field lines.

36.8 Meters to Motors

The principal difference between a galvanometer and an electric motor is that in an electric motor the current is made to change direction every time the coil makes a half revolution.

- A sensitive current-indicating instrument is called a *galvanometer.* A galvanometer calibrated to measure current (amperes) is called an *ammeter.* A galvanometer calibrated to measure electric potential (volts) is called a *voltmeter.*
- If the design of the galvanometer is slightly modified, you have an electric motor. Unlike a galvanometer, the current in an electric motor is reversed during each half revolution by means of stationary contacts on the shaft.

36.9 Earth's Magnetic Field

A compass points northward because Earth itself is a huge magnet.

- A compass aligns with the magnetic field of Earth. The discrepancy between the orientation of a compass and true north is known as the *magnetic declination.*
- Convection currents in the molten parts of Earth's interior may produce Earth's magnetic field.
- The magnetic field of Earth is not stable; it has flip-flopped throughout geologic time. These changes are recorded in Earth's rocks.

Exercises

36.1 Magnetic Poles (pages 721–722)

1. List two ways that magnets are like electric charges.
   a. ____
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   b. ____
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2. Regions that produce magnetic forces are called magnetic ________________.

3. Is the following sentence true or false? Every magnet, regardless of its shape, has both a north pole and a south pole. ________________

4. Write *attract* or *repel* to describe the effect of bringing the poles listed below together.
   ____________ a. the north pole of a bar magnet near the north pole of another bar magnet
   ____________ b. the north pole of a bar magnet near the south pole of another bar magnet
   ____________ c. the south pole of a bar magnet near the south pole of another magnet

5. Describe what happens if you break a bar magnet in half and then break each of the halves in half.
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36.2 Magnetic Fields (pages 722–723)

6. Define *magnetic field.*
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7. The direction of the magnetic field outside a magnet is from the ________________ pole to the ________________ pole.

8. Circle the letter of each statement about magnetic fields that is correct.
   a. Where the magnetic field lines are close together, the field strength is great.
   b. Where the magnetic field lines are far apart, the field strength is weak.
   c. Where the magnetic field lines are parallel, the field strength is zero.
   d. The field strength around a magnetic pole does not vary with distance.

9. Describe what happens if you place a magnetic compass near a bar magnet.

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36.3 The Nature of a Magnetic Field (pages 723–724)

10. Describe the two types of electron motion that produce the magnetic field in a bar magnet.

a. ____

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b. ____

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11. Of the two types of electron motion you described above, which one is more important in terms of the material's overall magnetic field?

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12. Explain why certain substances such as iron are magnetic but most substances are not.

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36.4 Magnetic Domains (pages 724–725)

13. What are magnetic domains?

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14. Is the following sentence true or false? The difference between a piece of ordinary iron and an iron magnet is the alignment of the magnetic domains. ________________

15. Describe what happens to the magnetic domains in an iron nail that is brought near a strong magnet.

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16. If an ordinary iron nail is removed from a strong magnet, the nail will lose its magnetism. Explain why this happens.

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17. How can you make a permanent magnet weaker?

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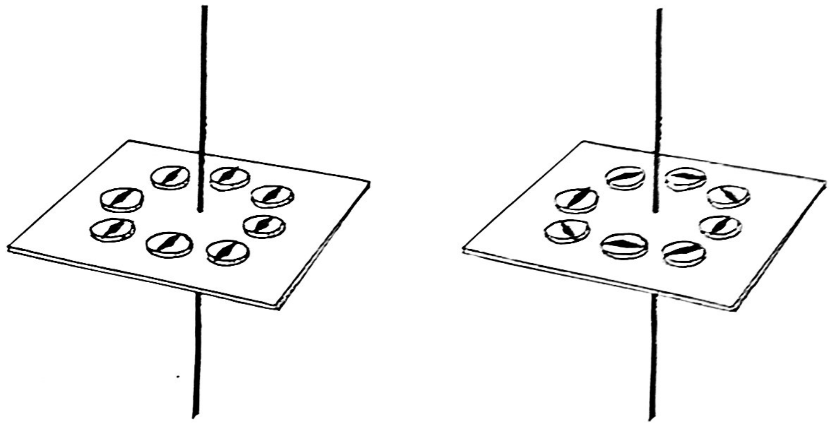
36.5 Electric Currents and Magnetic Fields (pages 726–727)

Use the diagrams below to answer Questions 18 and 19. Each diagram shows magnetic compasses placed around a conducting wire.



a. b.

18. Which of the diagrams shows a current-carrying wire? How do you know?

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19. Circle the letter of each sentence that correctly describes diagram (b).

a. The compass needles are aligned with Earth's magnetic field.

b. There is no current passing through the wire.

c. At the location of each compass, the magnetic field produced by the wire is stronger than Earth's magnetic field.

d. Charges moving through the wire produce a magnetic field pattern in the form of concentric circles about the wire.

20. Is the following sentence true or false? If a current-carrying wire is bent into a loop, the magnetic field strength inside the loop cancels to zero.

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21. Describe a simple electromagnet.

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22. Describe some uses for superconducting electromagnets.

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36.6 Magnetic Forces on Moving Charged Particles (page 728)

23. Listed below are descriptions of how a charged particle moves within a magnetic field. For each description, write *maximum, less than maximum,* or *zero* to describe how much force is exerted by the field on the particle.

______________ a. Particle is at rest in the field.

______________ b. Particle moves in a direction perpendicular to the magnetic field lines.

______________ c. Particle moves in a direction parallel to the magnetic field lines.

______________ d. Particle moves in a direction neither perpendicular nor parallel to the magnetic field lines.

24. The direction of force that a magnetic field exerts on a moving charged particle is always perpendicular to ______________________ and ______________________.

25. Explain how the effect of magnetic forces on charged particles helps protect Earth from cosmic radiation.

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36.7 Magnetic Forces on Current-Carrying Wires (page 729)

26. Is the following sentence true or false? A conducting wire experiences no deflecting force by a magnetic field as long as the wire carries current.

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27. Circle the letter of each correct statement about a current-carrying wire in a magnetic field.
    a. The force on the wire is maximum when the current is perpendicular to the magnetic field lines.
    b. The force on the wire is parallel to the current.
    c. If the direction of current in the wire is reversed, the deflecting force on the wire cancels to zero.
    d. If the direction of current in the wire is reversed, the deflecting force on the wire acts in the opposite direction.
28. Is the following sentence true or false? Just as a current-carrying wire will deflect a magnetic compass, a magnet will deflect a current-carrying wire. ______________

36.8 Meters to Motors (pages 730–731)

29. What is a galvanometer?

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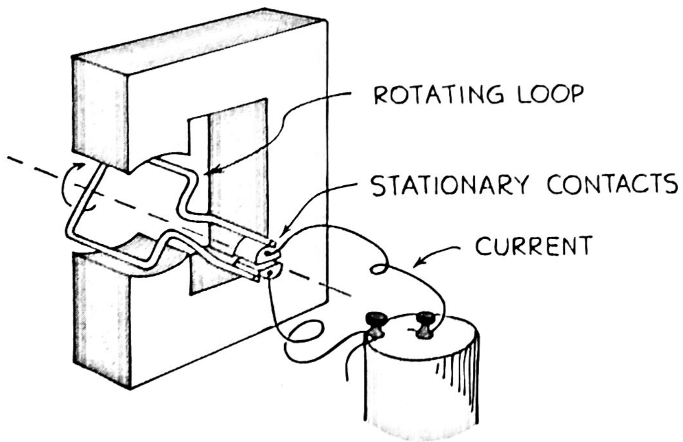
30. If a galvanometer is calibrated to measure current, it is called a(n) ______________. If a galvanometer is calibrated to measure electric potential, it is called a(n) ______________.
31. The diagram below shows a simplified DC motor. Explain the purpose of the stationary contacts.



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