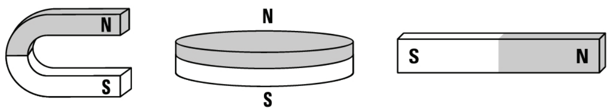
Pearson Physics Level 30
Unit VI Forces and Fields: Chapter 12
Solutions

Student Book page 583

Concept Check (top)



Concept Check (bottom)

The north-seeking needle of a compass is attracted to what is called Earth's magnetic north pole, indicating that there must be a south magnetic pole at that location.

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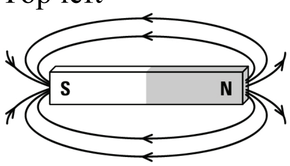
Concept Check (top)

Top left



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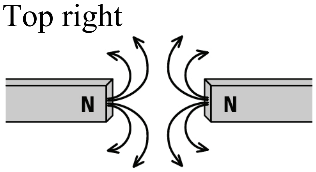

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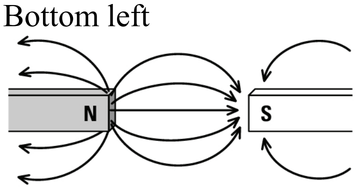

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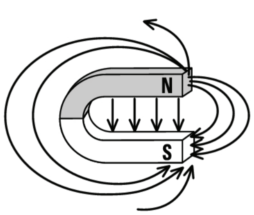

Concept Check (bottom)

Two similarities:

- Fields explain "action at a distance".
- They are represented by vector arrows, where the vector's length represents the magnitude of the field and the arrow represents its direction.
- Fields extend to infinity.
- Fields can exert forces on objects.

Two differences:

- Gravitational forces can only be attractive, whereas electric and magnetic forces can be attractive or repulsive.
- Magnetic fields originate from two separate poles, whereas electric and gravitational fields originate from the centre of a charge or mass.

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Skills Practice

1. (a) Using the left-hand rule, the thumb points in the direction of current and fingers point in the direction of the magnetic field, or clockwise (into the page).

(b) Using the left-hand rule, the thumb points toward the north end of the magnetic field in the coil. The fingers point out of the page, or counterclockwise.

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Concept Check

The filing cabinet has become a permanent magnet through prolonged contact with the influence of Earth's magnetic field. If it is a permanent magnet, it will have two poles, as evidenced by the effect of the top and bottom of the filing cabinet on a compass. If it was magnetized by the magnetic compass, magnetization would be by induction and the compass needle would point in the same direction when held near the top and the bottom of the cabinet.

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12.1 Check and Reflect

Knowledge

1. The law of magnetism states that like poles repel and unlike poles attract.

2. (a) Yes. Every magnet must have a north and south pole — the poles cannot exist alone.

(b) No. A negative or positive charge can exist by itself (e.g., a proton or an electron).

3. Gilbert compared the orientation of magnetized needles on the surface of a spherical piece of lodestone with the north-south orientation of a compass needle on various locations on Earth's surface.

4. (a) In a bar magnet, magnetism is caused by moving charges within the atoms.

(b) On Earth, magnetism is most probably caused by moving charges in the molten outer core.

5. Oersted discovered that moving electric charges create magnetic fields.

6. (a) The magnetic field around a straight current-carrying conductor forms concentric circles around the wire.

(b) The magnetic field within a coil of conducting wire carrying a current has a north and south pole and is straight except near the ends of the coil.

Applications

7. If you broke a magnet into two pieces, you would have two magnets.

8. The magnetic field around the moving sphere would be circular in a clockwise direction. If the sphere were positively charged, the magnetic field would be circular in a counterclockwise direction.

9. The magnetic field would be straight within the top with the north pole pointing upward at you. The field lines will start curving outside the top with some ending at the south pole, at the bottom.

10. (a) Differences: Gravitational fields have one direction toward the centre of mass, whereas electric fields can have two directions depending on the type of charge. Gravitational fields are created by all masses, whereas electric fields are created only by charged objects. Electric fields are much stronger and can exert influences that are attractive or repulsive.
Similarities: The magnitudes of electric fields around a point charge and gravitational fields both vary with $\frac{1}{r^2}$, and they both exert forces that cause action at a distance.

(b) Differences: Gravitational fields have one direction toward the centre of mass, whereas magnetic fields extend from one pole to another. Gravitational fields are created by all masses, whereas magnetic fields are created only by magnetic objects. Magnetic fields are much stronger, and they can be attractive or repulsive.
Similarities: The magnitudes of gravitational and magnetic fields vary inversely with distance, and they both exert forces that cause action at a distance.

(c) Differences: Electric fields can exist around a single charge, whereas magnetic fields must have two poles. Electric fields exist whether charges are stationary or moving, whereas all magnetic fields are caused by moving charges.
Similarities: Electric fields and magnetic fields both exert influences that are attractive or repulsive, and they both exert forces that cause action at a distance.

11. (a) As the magnet approaches the unmagnetized material, the domains in the right orientation for attraction to the pole of the magnet grow at the expense of other domains. The material has been magnetized by induction and has become a temporary magnet. Attraction occurs.

(b) As a magnet strokes a nail, the domains shift in the direction of the stroking. The nail has been magnetized by contact and has become a permanent magnet. Attraction occurs.

(c) The compass is a tiny magnet. As the compass approaches the metal leg, the domains in the metal leg in the right orientation for attraction to the pole of the compass grow at the expense of other domains. The leg has been magnetized by induction and has become a temporary magnet. Attraction occurs.

12. Dropping or heating a bar magnet will return some or all the domains back to a random orientation.

13. The magnetic fields extend from one pole to the other in both the magnet and Earth and are strongest near the poles. However, the magnetic field of Earth appears to run from south to north, whereas a bar magnet's magnetic field runs from north to south.

Extensions

14. The magnetic fields at the poles point straight down to the surface, which makes it difficult to get an accurate bearing with a magnetic compass near the poles.

15. No. The lines are parallel to Earth's surface only at the equator. Away from the equator, the lines gradually begin to dip toward Earth's surface so that, at the poles, the lines point straight down.

16. There is a greater concentration of magnetic field lines within the loop than outside the loop, so the magnetic field is stronger inside the loop.

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Skills Practice

1. (a) The magnetic field points out of the page.
(b) The negative charge moves into the page.
(c) The positive charge moves into the page.

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Concept Check

Comparing the magnetic force with the gravitational force on a moving charge:

- When a mass or a charge moves perpendicularly through a gravitational or a uniform magnetic field, respectively, the gravitational force causes a mass to accelerate in a parabolic path, whereas the magnetic force on a moving charge causes the charge to accelerate in a circular path.
- When a mass moves parallel to a gravitational field, it will accelerate in the direction of the field. A charge is unaffected when moving parallel to magnetic fields.

Comparing the magnetic force on a moving charge with the electric force due to another nearby charge:

- When a charge moves perpendicularly through uniform magnetic or electric fields, respectively, the magnetic force on a moving charge causes the charge to accelerate in a circular path, whereas the electric force causes a charge to accelerate in a parabolic path.
- When a charge moves parallel to an electric field, it will accelerate in the direction of the field. A charge is unaffected when moving parallel to a magnetic field.

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Example 12.1 Practice Problems

1. ***Given***

$q = +1.60 \times 10^{-19}$ C

$\left|\vec{B}\right| = 4.20 \times 10^{-4}$ T

$v_{\perp} = 3.50 \times 10^{4}$ m/s

Required
magnitude of the magnetic deflecting force on the proton ($|\vec{F}_m|$)

Analysis and Solution
To calculate the magnitude of the magnetic deflecting force, use:

$$\begin{aligned}|\vec{F}_m| &= qv_{\perp}|\vec{B}| \\ &= (1.60 \times 10^{-19}\ \text{C})(3.50\times10^{4}\ \text{m/s})(4.20\times10^{-4}\ \text{T}) \\ &= 2.35\times10^{-18}\ \text{N}\end{aligned}$$

Paraphrase
The magnitude of the magnetic deflecting force on the proton is 2.35×10^{-18} N.

2. ***Given***
$q = +3.20\times10^{-19}$ C
$|\vec{B}| = 2.20\times10^{-1}$ T
$v_{\perp} = 2.30\times10^{5}$ m/s [30°]

Required
magnitude of the magnetic deflecting force on the ion ($|\vec{F}_m|$)

Analysis and Solution
To calculate the magnitude of the magnetic deflecting force, use:

$$\begin{aligned}|\vec{F}_m| &= qv_{\perp}|\vec{B}| \\ &= (3.20\times10^{-19}\ \text{C})(2.30\times10^{5}\ \text{m/s})(\sin 30°)(2.20\times10^{-1}\ \text{T}) \\ &= 8.10\times10^{-15}\ \text{N}\end{aligned}$$

Paraphrase
The magnitude of the magnetic deflecting force on the ion is 8.10×10^{-15} N.

3. Using the left-hand rule:
- thumb — in the direction of the sphere's motion from west to east
- fingers — in the direction of Earth's magnetic field from south to north
- palm — downward toward Earth's surface, indicating the direction of deflection

The direction of the magnetic deflecting force on the sphere is downward, toward Earth's surface.

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Example 12.2 Practice Problems

1. ***Given***
$m = 9.11\times10^{-31}$ kg
$|\vec{B}| = 5.00\times10^{-5}$ T
$q = -1.60\times10^{-19}$ C
$\vec{g} = 9.81$ N/kg [down]

Required
minimum speed required for the electron to remain at the same height above Earth's surface (v)

Analysis and Solution

The gravitational force on the electron is $\vec{F}_g = m\vec{g}$ [downward].

The magnetic deflecting force on the electron is $\left|\vec{F}_m\right| = qv_\perp\left|\vec{B}\right|$ [upward].

To maintain the electron at the same height, the magnetic deflecting force must balance the gravitational force:

$$\left|\vec{F}_m\right| = \left|\vec{F}_g\right|$$

$$qv_\perp\left|\vec{B}\right| = mg$$

$$v_\perp = \frac{mg}{\left|\vec{B}\right|q}$$

$$= \frac{(9.11\times10^{-31}\ \text{kg})\left(9.81\ \frac{\text{N}}{\text{kg}}\right)}{(5.00\times10^{-5}\ \text{T})(1.60\times10^{-19}\ \text{C})}$$

$$= 1.12\times10^{-6}\ \text{m/s}$$

Paraphrase

The minimum speed required for the electron to remain at the same height above Earth's surface is 1.12×10^{-6} m/s.

2. ***Given***

$q = 1.60\times10^{-19}$ C

$\left|\vec{B}\right| = 0.150$ T

$v_\perp = 8.00\times10^4$ m/s

$m = 8.12\times10^{-26}$ kg

Required

(a) magnitude of the deflecting force on the ion ($\left|\vec{F}_m\right|$)

(b) radius of curvature of the motion of the deflected ion (r)

Analysis and Solution

(a) To calculate the magnitude of the deflecting force, use:

$$\left|\vec{F}_m\right| = qv_\perp\left|\vec{B}\right|$$

$$= (1.60\times10^{-19}\ \text{C})(8.00\times10^4\ \text{m/s})(0.150\ \text{T})$$

$$= 1.92\times10^{-15}\ \text{N}$$

(b) When the ion is in circular motion within the magnetic field, $\left|\vec{F}_m\right| = \left|\vec{F}_c\right|$.

To determine the radius of the curvature, use:

$$qv_{\perp}\left|\vec{B}\right| = \frac{mv^2}{r}$$

$$r = \frac{mv_{\perp}}{q\left|\vec{B}\right|}$$

$$= \frac{(8.12 \times 10^{-26}\text{ kg})(8.00 \times 10^{4}\text{ m/s})}{(1.60 \times 10^{-19}\text{ C})(0.150\text{ T})}$$

$$= 0.271\text{ m}$$

Paraphrase

(a) The magnitude of the deflecting force is 1.92×10^{-15} N.
(b) The radius of curvature of the motion of the deflected ion is 0.271 m.

Student Book page 601

12.2 Check and Reflect

Knowledge

1. It is called a cathode ray because the rays appeared to originate from the cathode of a vacuum tube.

2. A magnetic field vector arrow indicates the magnitude and direction of the magnetic field at a particular point. A magnetic field line is a continuous curve (or a straight line), which shows the direction and the shape of the field.

3. The particles will deflect in opposite directions, with the proton making a larger arc because of its larger mass.

4. A moving charge that enters perpendicular to each uniform field is deflected in a circular path in a magnetic field and in a parabolic path in an electric field. When the moving charge enters parallel to each field, it accelerates along the electric field lines and is unaffected in the magnetic field.

Applications

5. (a) No deflection. A charged particle must travel perpendicular to the external magnetic field to be deflected.
(b) The lithium ion will be deflected downward to the surface of Earth.
(c) The lithium ion will initially be deflected westward along the surface of Earth.

6. (a) ***Given***

$q = +1.60 \times 10^{-19}$ C

$\left|\vec{B}\right| = 0.200$ T

$v = 2.00 \times 10^{5}$ m/s

Required

(a) magnitude of the deflecting force if the proton enters perpendicular to the magnetic field ($\left|\vec{F}_{\text{m}}\right|$)

(b) magnitude of the deflecting force if the proton enters the magnetic field at an angle of 35.0° ($\left|\vec{F}_{\text{m}}\right|$)

Analysis and Solution

(a) To calculate the magnitude of the deflecting force, use:

$$\begin{aligned}\left|\vec{F}_{\text{m}}\right| &= qv_{\perp}\left|\vec{B}\right| \\ &= (1.60 \times 10^{-19}\ \text{C})(2.00 \times 10^{5}\ \text{m/s})(0.200\ \text{T}) \\ &= 6.40 \times 10^{-15}\ \text{N}\end{aligned}$$

(b) To calculate the magnitude of the deflecting force, use:

$$\begin{aligned}\left|\vec{F}_{\text{m}}\right| &= qv_{\perp}\left|\vec{B}\right| \\ &= (1.60 \times 10^{-19}\ \text{C})(2.00 \times 10^{5}\ \text{m/s})(\sin 35.0°)(0.200\ \text{T}) \\ &= 3.67 \times 10^{-15}\ \text{N}\end{aligned}$$

Paraphrase

(a) The magnitude of the deflecting force if the proton enters perpendicular to the magnetic field is 6.40×10^{-15} N.

(b) The magnitude of the deflecting force if the proton enters the magnetic field at an angle of 35.0° is 3.67×10^{-15} N.

7. ***Given***

$m = 0.020\ \text{g} = 2.0 \times 10^{-5}\ \text{kg}$

$\left|\vec{B}\right| = 5.0 \times 10^{-5}\ \text{T}$

$q = -3.0 \times 10^{-6}\ \text{C}$

$\vec{g} = 9.81\ \text{N/kg [down]}$

Required

speed required to maintain the motion of the ball at the same height (v)

Analysis and Solution

The gravitational force on the ball is $\vec{F}_{\text{g}} = m\vec{g}$ [downward].

The magnetic deflecting force on the ball is $\left|\vec{F}_{\text{m}}\right| = qv_{\perp}\left|\vec{B}\right|$ [upward].

To maintain the speed with the same horizontal motion, the magnetic deflecting force must balance the gravitational force:

$$\begin{aligned}\left|\vec{F}_{\text{m}}\right| &= \left|\vec{F}_{\text{g}}\right| \\ qv_{\perp}\left|\vec{B}\right| &= mg \\ v_{\perp} &= \frac{mg}{\left|\vec{B}\right|q} \\ &= \frac{(2.0 \times 10^{-5}\ \cancel{\text{kg}})(9.81\ \text{N/kg})}{(5.0 \times 10^{-5}\ \text{T})(3.0 \times 10^{-6}\ \text{C})} \\ &= 1.3 \times 10^{6}\ \text{m/s}\end{aligned}$$

Paraphrase

The ball must be thrown with a speed of 1.3×10^{6} m/s.

8. ***Given***

$\left|\vec{B}\right| = 2.00 \times 10^{-2}$ T

$v_{\perp} = 1.02 \times 10^{-5}$ m/s

$q = 2 \times +1.60 \times 10^{-19}$ C $= +3.20 \times 10^{-19}$ C

Required

minimum gravitational force required to maintain the alpha particle at the same height above Earth's surface ($\left|\vec{F}_{\text{g}}\right|$)

Analysis

The gravitational force on the alpha particle is $\vec{F}_{\text{g}} = m\vec{g}$ [downward].

The magnetic deflecting force on the alpha particle is $\left|\vec{F}_{\text{m}}\right| = qv_{\perp}\left|\vec{B}\right|$ [upward].

To maintain the alpha particle at the same height, the magnetic deflecting force must balance the gravitational force:

$$\left|\vec{F}_{\text{m}}\right| = \left|\vec{F}_{\text{g}}\right|$$

$$qv_{\perp}\left|\vec{B}\right| = mg$$

To calculate the gravitational force required, use:

$$\begin{aligned}\left|\vec{F}_{\text{g}}\right| &= qv_{\perp}\left|\vec{B}\right| \\ &= (3.20 \times 10^{-19}\text{ C})(1.02 \times 10^{-5}\text{ m/s})(2.00 \times 10^{-2}\text{ T}) \\ &= 6.53 \times 10^{-26}\text{ N}\end{aligned}$$

Paraphrase

The minimum gravitational force on the alpha particle is 6.53×10^{-26} N.

9. ***Given***

$q = -1.60 \times 10^{-19}$ C

$\left|\vec{B}\right| = 0.0700$ T

$v_{\perp} = 1.30 \times 10^{6}$ m/s

$m = 9.11 \times 10^{-31}$ kg

Required

radius of deflection of the electrons in the tube (r)

Analysis and Solution

When the electrons are in circular motion within the magnetic field, $\left|\vec{F}_{\text{m}}\right| = \left|\vec{F}_{\text{c}}\right|$. F_g is ignored because it is very small compared with F_m.

$$qv\left|\vec{B}\right| = \frac{mv^2}{r}$$

$$\begin{aligned}r &= \frac{mv}{q\left|\vec{B}\right|} \\ &= \frac{(9.11 \times 10^{-31}\text{ kg})(1.30 \times 10^{6}\text{ m/s})}{(1.60 \times 10^{-19}\text{ C})(0.0700\text{ T})} \\ &= 1.06 \times 10^{-4}\text{ m}\end{aligned}$$

Paraphrase

The radius of deflection of the electrons in the tube is 1.06×10^{-4} m.

10. ***Given***

$q = +1.60 \times 10^{-19}$ C

$v = 4.38 \times 10^{6}$ m/s

$m = 1.67 \times 10^{-27}$ kg

$r = 5.50 \times 10^{6}$ m

Required

magnitude of the magnetic field ($|\vec{B}|$)

Analysis and Solution

When the electrons are in circular motion within the magnetic field, $|\vec{F}_{\text{m}}| = |\vec{F}_{\text{c}}|$.

$$qv|\vec{B}| = \frac{mv^2}{r}$$

$$|\vec{B}| = \frac{mv}{qr}$$

$$= \frac{(1.67 \times 10^{-27}\text{ kg})(4.38 \times 10^{6}\text{ m/s})}{(1.60 \times 10^{-19}\text{ C})(5.50 \times 10^{6}\text{ m})}$$

$$= 8.31 \times 10^{-9}\text{ T}$$

Paraphrase

The magnitude of the magnetic field at that point in space is 8.31×10^{-9} T.

Extension

11. It is only at the higher latitudes that the magnetic field lines, which have trapped charged particles from space, enter the atmosphere of Earth.

Student Book page 603

Example 12.3 Practice Problems

1. ***Given***

$q = 20.0$ C

$t = 1.00\text{ ms} = 1.00 \times 10^{-3}$ s

Required

current (I)

Analysis and Solution

$$I = \frac{q}{t}$$

$$= \frac{20.0\text{ C}}{1.00 \times 10^{-3}\text{ s}}$$

$$= 2.00 \times 10^{4}\text{ A}$$

Paraphrase

The current during the lightning strike is 2.00×10^{4} A .

2. ***Given***

$I = 5.00 \text{ A}$

$t = 10.0 \text{ s}$

Required

charge (q)

Analysis and Solution

$$I = \frac{q}{t}$$

$$\begin{aligned} q &= It \\ &= (5.00 \text{ A})(10.0 \text{ s}) \\ &= 50.0 \text{ C} \end{aligned}$$

Paraphrase

The amount of charge that passes through the appliance is 50.0 C.

Student Book page 605

Example 12.4 Practice Problems

1. ***Given***

$l_{\perp} = 0.500 \text{ m}$

$|\vec{B}| = 0.200 \text{ T}$

$I = 10.0 \text{ A}$

Required

magnitude of the magnetic force on the wire ($|\vec{F}_{\text{m}}|$)

Analysis and Solution

To calculate the magnitude of the magnetic force, use:

$$\begin{aligned} |\vec{F}_{\text{m}}| &= Il_{\perp}|\vec{B}| \\ &= (10.0 \text{ A})(0.500 \text{ m})(0.200 \text{ T}) \\ &= 1.00 \text{ N} \end{aligned}$$

Paraphrase

The magnitude of the magnetic force on the wire is 1.00 N.

2. ***Given***

$l_{\perp} = 0.75 \text{ m}$

$|\vec{B}| = 0.15 \text{ T}$

$m = 0.060 \text{ kg}$

Required

minimum current (I)

Analysis and Solution

The magnitude of the magnetic force is given by:

$$|\vec{F}_{\text{m}}| = Il_{\perp}|\vec{B}|$$

The magnitude of the gravitational force is given by:

$$|\vec{F}_{\text{g}}| = mg$$

To suspend the wire, the magnetic force must balance the gravitational force:

$$\left|\vec{F}_{\mathrm{m}}\right| = \left|\vec{F}_{\mathrm{g}}\right|$$

$$Il_{\perp}\left|\vec{B}\right| = mg$$

$$I = \frac{mg}{l_{\perp}\left|\vec{B}\right|}$$

$$= \frac{(0.060\ \mathrm{kg})(9.81\ \mathrm{N/kg})}{(0.75\ \mathrm{m})(0.15\ \mathrm{T})}$$

$$= 5.2\ \mathrm{A}$$

Paraphrase

The minimum current required to make the wire "float" in the magnetic field is 5.2 A.

Student Book page 608

Concept Check

The wires are crossed to cancel magnetic fields in a region.

Student Book page 609

Concept Check

To cause the armature to rotate counterclockwise, reverse the direction of the electric current or switch the permanent magnets.

Student Book page 613

12.3 Check and Reflect

Knowledge

1. The factors that affect the magnetic force on a moving charge through an external magnetic field are the quantity of charge, the magnitude of the magnetic field, and the speed of the charge perpendicular to the magnetic field.

2. The factors that affect the magnetic force on a charge moving through a conducting wire in an external magnetic field are the quantity of current in the conducting wire, the magnitude of the magnetic field, and the length of conducting wire perpendicular to the magnetic field.

3. An ampere is the flow of one coulomb of charge past a point in a conductor in 1 s.
$1\ \text{ampere} = 1\ \text{coulomb/s or } 1\ \mathrm{C} = 1\ \mathrm{A} \cdot \mathrm{s}$

4. **(a)** A similarity between motors and generators is that they both consist of an external magnetic field, a rotating loop of wire, and a commutator.

(b) A difference is that a simple electric motor uses electricity to produce mechanical energy and a simple electric generator uses mechanical energy to produce electricity.

5. Faraday and Henry applied the symmetry between electricity and magnetism.

6. The split-ring commutator changes the direction of the current in the coil, every half-rotation of the coil. It also prevents twisting of wires in the external circuit.
7. Electrons in a rotating loop of wire gain energy from the work done in rotating the coil that initiates electromagnetic induction.

Applications

8. According to the left-hand rule for a wire in a magnetic field, the wire should deflect upward (toward the top of the page).
9. To determine the quantity of charge, use the equation

$$I = \frac{q}{t}$$

$$\begin{aligned} q &= It \\ &= (5.20 \times 10^{-3}\ \text{A})(2.00\ \text{s}) \\ &= 1.04 \times 10^{-2}\ \text{C} \end{aligned}$$

The quantity of charge that flows through the circuit in 2.00 s is 1.04×10^{-2} C.

10. Currents in opposite directions should repel. See Figure 12.31(b) on page 607 of the student book.
11. To calculate the magnitude of the magnetic force, use:

$$\begin{aligned} \left|\vec{F}_{\text{m}}\right| &= Il_{\perp}\left|\vec{B}\right| \\ &= (0.56\ \text{A})(0.50\ \text{m})(0.30\ \text{T}) \\ &= 8.4 \times 10^{-2}\ \text{N} \end{aligned}$$

The magnitude of the magnetic force is 8.4×10^{-2} N.

Extension

12. Yes. To convert a generator to a motor, you must supply current to the loop of wire in the magnetic field and attach an axle to the loop to rotate the loop of the new motor. A split-ring commutator must also be attached if the supplied current is DC.

Student Book page 618

Concept Check

When the north pole of the magnet is directed downward, a clockwise current is induced in the tube and a north pole is induced at the top end of the tube. If the south pole of the magnet were directed downward, it would induce a south pole at the top end of the tube and a counterclockwise current.

Student Book page 620

12.4 Check and Reflect

Knowledge

1. **(a)** Students are most likely to identify examples from the text: an electric motor and a loudspeaker.
   (b) Students are most likely to identify examples from the text: a generator and a transformer.
2. The three basic components of an electric motor and generator are the external magnetic field, a rotating loop of conducting wire, and a commutator.

3. The direction of a magnetically induced current is such as to oppose the cause of the current.

Applications

4. (a) You must supply electric current.

(b) As the electric current moves through the magnetic field, the interaction of its magnetic field with the external magnetic field creates a turning effect, resulting in mechanical energy from the device.

(c) As the magnetic force moves the wire through the external magnetic field, it cuts magnetic field lines. This effect produces a voltage that induces a current in the wire, which is in a direction opposite to the original flow of charges in the wire.

5. (a) You must supply mechanical energy to turn the wires to cut through an external magnetic field.

(b) As the wire moves through the magnetic field, it cuts magnetic field lines, which produces a voltage that induces a current in the wire.

(c) The induced current is a flow of charges in the wire, which creates a magnetic field. The interaction of this magnetic field with the external magnetic field creates a magnetic force on the charges and the wire, causing the wire to move in a direction opposite to its original direction.

6. As you move a magnet toward a coil of wire, the coil of wire cuts the magnetic field lines. This effect produces a potential difference that induces a current in the coil. The induced current produces a magnetic field. This new magnetic field will always repel the magnetic field of the magnet.

7. The direction of the induced current in the ring is counterclockwise looking at the ring from the right.

Extensions

8. If the current were in the same direction, then the total current in the wire would be more than what was originally supplied, which would violate the law of conservation of energy.

9. If the motor is prevented from rotating, the opposing current that should exist according to Lenz's law is not being produced. Too much current is now present in the loop, and the loop will overheat.

Student Book pages 622–623

Chapter 12 Review

Knowledge

1. (a) Gilbert was the first to suggest the concept of "orbs of influence" surrounding magnets in attempting to explain action at a distance. This concept was the first notion of a magnetic field. He also established the concept of Earth as a large magnet.

(b) Oersted was the first to demonstrate the relationship between electricity and magnetism by showing that moving charges produce magnetic fields.

(c) Ampère demonstrated that two current-carrying conductors exert magnetic forces on each other. By establishing the variables that affect the magnetic force between two current-carrying conductors, he was able to define a unit of current that we now call the ampere.

(d) Faraday is given credit for establishing the relationship between magnetism and electricity. He was able to demonstrate that moving a conductor through a magnetic field will generate a current in the conductor, thus proving electromagnetic induction.

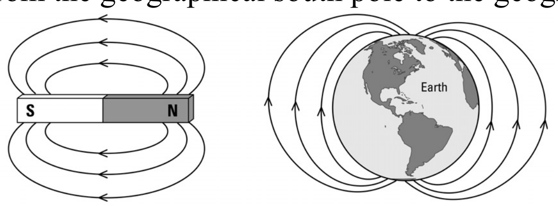
2. (a) A magnetic field is a region of magnetic influence around a magnet in which other magnets or magnetic substances are affected by magnetic forces.

(b) The direction of a magnetic field is the direction of the force on the north pole of a compass placed in the field.

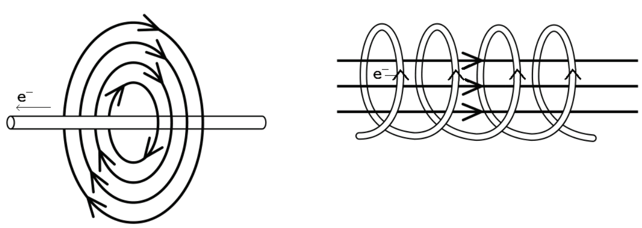
3. A magnetic vector arrow indicates the magnitude and the direction of the magnetic field at a point in the magnetic field. A magnetic field line extends from the north pole to the south pole of a magnet and only displays direction. The density of the magnetic field lines indicates the magnitude of the field.

4. Two magnetic objects can either attract or repel each other, depending on their orientation to each other. Therefore, there must be two types of poles.

5. (a) Magnetic field lines run from the north pole to the south pole on a bar magnet and from the geographical south pole to the geographical north pole on Earth.



(b) A straight current-carrying conductor has circular magnetic field lines around the conductor. In the left diagram below, current direction is left and the magnetic field direction is counterclockwise, viewing from the right. In the right diagram below, a coil of conducting wire with current in a clockwise direction, viewed from the right, has a straight magnetic field running to the right through the centre of the coil.



straight conducting wire　　　coil of conducting wire

6. The external magnets and the moving charge produce the two magnetic fields that provide the magnetic force of the motor effect.

7. (a) If the charge moves parallel to the external magnetic field lines, it is not deflected.

(b) If it moves perpendicular to the external magnetic field lines, the charge will deflect in a circular path.

(c) If it enters the magnetic field at an angle, the charge deflects in a circular motion that becomes a helix.

8. A magnetic bottle is formed in the Van Allen belt around Earth where charged particles oscillate back and forth between Earth's magnetic poles.

9. A galvanometer is a sensitive instrument that can detect very small currents. An ammeter is a galvanometer designed to measure large currents.

10. One ampere of current exists when 1 C of charge passes a point in a conductor every 1 s. A current of 1 A flows in two parallel, long, straight wires in the same direction, 1 m apart, if the wires attract each other with a force of 2×10^{-7} N/m.

11. In both parts, students' answers may vary, but are likely to be the following:

(a) electric motors and meters

(b) electric generators and transformers

12. Lenz's law states that the direction of a magnetically induced current is such as to oppose the cause of the current. This means that whatever you supply into a system, something will be produced to hinder what you supply. One example is a motor acting as a generator to produce a current that will oppose the direction of the original current in the motor. This affects the operation of both motors and generators.

Applications

13. Every charged object does not necessarily have a negative and a positive charge. An electron can exist as a negative charge by itself. A magnetized object must have a north and a south pole because there is no magnetic monopole.

14. Within the magnet, the direction of the field points from the south to the north pole so that the field lines form closed loops.

15. (a) During magnetization by induction, the domains in the right orientation for attraction to an external magnet grow at the expense of the other domains, creating a temporary magnet.

(b) During magnetization by contact, all domains shift in the direction of the external magnet, creating a permanent magnet.

16. $\left|\vec{F}_{\text{m}}\right| = qv\left|\vec{B}\right|$, so:

(a) if the charge is doubled, the force is doubled

(b) if the magnetic field is doubled and the speed is halved, the force doesn't change

(c) if the mass is doubled, there is no effect on the magnitude of the force

17. In a permanent magnet, all domains within the substance are aligned in one direction. In a temporary magnet, only the domains in the right orientation for attraction to an external magnetic influence grow at the expense of the other domains. No domains shift in the formation of temporary magnets.

18. Hold the compass over the current-carrying wire. You can determine the direction of the current in the wire by observing the direction of the compass needle and using the left-hand wire-grasp rule.

19. The grape is a diamagnetic substance, which always opposes an external magnetic field.

20. ***Given***

$q = -1.60\times10^{-19}$ C

$\left|\vec{B}\right| = 0.0880$ T

$v_{\perp} = 7.00\times10^{6}$ m/s

Required

magnitude of the magnetic deflecting force on the electron ($\left|\vec{F}_{\text{m}}\right|$)

Analysis and Solution

To calculate the magnitude of the magnetic deflecting force, use:

$$\left|\vec{F}_m\right| = qv_\perp \left|\vec{B}\right|$$
$$= (1.60 \times 10^{-19}\ \text{C})(7.00 \times 10^{6}\ \text{m/s})(0.0880\ \text{T})$$
$$= 9.86 \times 10^{-14}\ \text{N}$$

Paraphrase

The magnitude of the magnetic deflecting force on the electron is 9.86×10^{-14} N.

21. ***Given***

$q = +1.60 \times 10^{-19}$ C

$\left|\vec{B}\right| = 2.60 \times 10^{-2}$ T

$\left|\vec{F}_m\right| = 5.50 \times 10^{-17}$ N

$\theta = 35°$

Required

(a) speed of the proton at an angle of 35° (v)

(b) kinetic energy of the proton in J and eV (E_k)

Analysis and Solution

(a) Determine the speed of the proton:

$$\left|\vec{F}_m\right| = qv_\perp \left|\vec{B}\right|$$
$$v_\perp = \frac{\left|\vec{F}_m\right|}{q\left|\vec{B}\right|}$$
$$= \frac{5.50 \times 10^{-17}\ \text{N}}{(1.60 \times 10^{-19}\ \text{C})(2.60 \times 10^{-2}\ \text{T})}$$
$$= 1.322 \times 10^{4}\ \text{m/s}$$

Determine the speed of the proton at 35°:

$$v = \frac{v_\perp}{\sin 35°}$$
$$= \frac{1.322 \times 10^{4}\ \text{m/s}}{\sin 35°}$$
$$= 2.305 \times 10^{4}\ \text{m/s}$$
$$= 2.31 \times 10^{4}\ \text{m/s}$$

(b) To determine the kinetic energy of the proton, use:

$$E_k = \frac{1}{2}mv^2$$
$$= \frac{1}{2}\left(1.67 \times 10^{-27}\ \text{kg}\right)\left(2.305 \times 10^{4}\ \text{m/s}\right)^2$$
$$= 4.437 \times 10^{-19}\ \text{J}$$
$$= \left(4.437 \times 10^{-19}\ \cancel{\text{J}}\right)\left(\frac{1\ \text{eV}}{1.60 \times 10^{-19}\ \cancel{\text{J}}}\right)$$
$$= 2.77\ \text{eV}$$

The kinetic energy of the proton is 4.44×10^{-19} J or 2.77 eV.

Paraphrase

(a) The speed of the proton at 35° to the magnetic field is 2.31×10^4 m/s.

(b) The kinetic energy of the proton is 4.44×10^{-19} J or 2.77 eV.

22. ***Given***

$m = 6.65 \times 10^{-27}$ kg

$|\vec{B}| = 50.0\ \mu\text{T} = 50.0 \times 10^{-6}$ T

$q = 2 \times 1.60 \times 10^{-19}$ C

$g = 9.81$ N/kg

Required

speed required to maintain the motion of the alpha particle at the same height within Earth's magnetic and gravitational fields (v)

Analysis and Solution

The gravitational force on the alpha particle is $\vec{F}_g = m\vec{g}$ [downward].

The magnetic deflecting force on the alpha particle is $|\vec{F}_m| = qv_\perp|\vec{B}|$ [upward].

For the alpha particle to maintain its speed at the same height, the magnetic force must balance the gravitational force:

$$|\vec{F}_m| = |\vec{F}_g|$$

$$qv_\perp|\vec{B}| = mg$$

To calculate the speed required, use:

$$\begin{aligned} v_\perp &= \frac{mg}{|\vec{B}|q} \\ &= \frac{(6.65 \times 10^{-27}\ \cancel{\text{kg}})\left(9.81 \frac{\text{N}}{\cancel{\text{kg}}}\right)}{(50.0 \times 10^{-6}\ \text{T})(2 \times 1.60 \times 10^{-19}\ \text{C})} \\ &= 4.08 \times 10^{-3}\ \text{m/s} \end{aligned}$$

Paraphrase

The speed that the alpha particle must maintain to remain at the same height is 4.08×10^{-3} m/s.

23. ***Given***

$q = 2 \times 1.60 \times 10^{-19}$ C

$|\vec{B}| = 0.0300$ T

$v_\perp = 4.30 \times 10^4$ m/s

Required

(a) magnitude of the magnetic force on the alpha particle perpendicular to the magnetic field ($|\vec{F}_m|$)

(b) magnitude of the magnetic force 30.0° to the magnetic field ($|\vec{F}_m|$)

(c) magnitude of the magnetic force parallel to the magnetic field ($|\vec{F}_m|$)

Analysis and Solution

(a) To calculate the magnitude of the magnetic force, use:

$$\left|\vec{F}_m\right| = qv_{\perp}\left|\vec{B}\right|$$
$$= (2 \times 1.60 \times 10^{-19}\ \text{C})(4.30 \times 10^{4}\ \text{m/s})(0.0300\ \text{T})$$
$$= 4.13 \times 10^{-16}\ \text{N}$$

(b) To calculate the magnitude of the magnetic force, use:

$$\left|\vec{F}_m\right| = qv_{\perp}\left|\vec{B}\right|$$
$$= (2 \times 1.60 \times 10^{-19}\ \text{C})(4.30 \times 10^{4}\ \text{m/s})(\sin 30.0°)(0.0300\ \text{T})$$
$$= 2.06 \times 10^{-16}\ \text{N}$$

(c) There will be no force on the alpha particle when it travels parallel to the external magnetic field.

Paraphrase

(a) The magnitude of the magnetic force on the alpha particle as it enters perpendicular to the magnetic field is 4.13×10^{-16} N.

(b) The magnitude of the magnetic force on the alpha particle as it enters the magnetic field at an angle of 30.0° is 2.06×10^{-16} N.

(c) The particle will experience no deflecting force when it enters parallel to a magnetic field.

24. ***Given***

$q = -1.60 \times 10^{-19}$ C

$v = 1.2 \times 10^{6}$ m/s

$m = 9.11 \times 10^{-31}$ kg

$r = 0.25$ m

Required

magnitude of the magnetic field required to bend the electron beam ($\left|\vec{B}\right|$)

Analysis and Solution

When the electrons are in circular motion within the magnetic field:

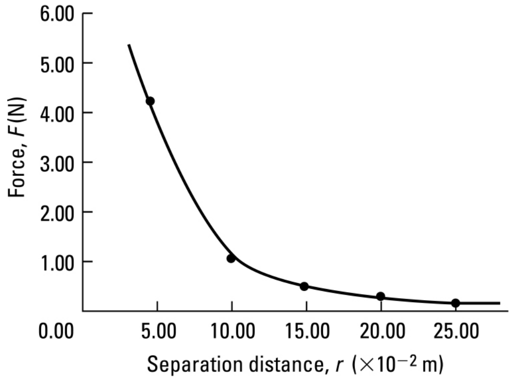
$$\left|\vec{F}_m\right| = \left|\vec{F}_c\right|$$
$$qv\left|\vec{B}\right| = \frac{mv^2}{r}$$
$$\left|\vec{B}\right| = \frac{mv}{qr}$$
$$= \frac{(9.11 \times 10^{-31}\ \text{kg})(1.2 \times 10^{6}\ \text{m/s})}{(1.60 \times 10^{-19}\ \text{C})(0.25\ \text{m})}$$
$$= 2.7 \times 10^{-5}\ \text{T}$$

Paraphrase

The magnitude of the magnetic field required to bend the electron beam is 2.7×10^{-5} T.

25. The source of the force of attraction is a magnetic force of attraction between the magnetic fields produced by the currents in each conductor. This force could not be electrostatic attraction because charges flowing in the wires are of the same sign. So if there is any electrostatic force, it should be a repulsive one rather than an attractive one.

26. **(a)** Graph of Magnetic Force vs. Separation Distance



(b) The shape of the graph indicates that $\vec{F}_{\mathrm{m}} \propto \frac{1}{r^2}$, since the product of $r^2\ F_{\mathrm{m}}$ is a constant (~100).

27. Over the poles, the direction of Earth's magnetic field is downward toward the surface. As the plane's wings, which are conductors, cut through the external magnetic field lines, a current is generated in the wings due to the generator effect. The left-hand rule for the generator effect shows that the right wing would have more electrons.

28. Determine the magnitude of the magnetic force:

$$\begin{aligned} \left|\vec{F}_{\mathrm{m}}\right| &= Il_{\perp}\left|\vec{B}\right| \\ &= (500\ \mathrm{A})(100\,\mathrm{m})(50.0 \times 10^{-6}\ \mathrm{T}) \\ &= 2.50\ \mathrm{N} \end{aligned}$$

The magnitude of the magnetic force on the wire is 2.50 N.

Extensions

29. The glass tube will allow the magnet to fall faster, because the only force on the magnet is the force of gravity. The magnet falling through the copper tube produces a current in the tube, which produces a magnetic field that opposes the motion of the magnet, according to Lenz's Law.

30. The steel balls have become magnetized by induction and are attracted to the disk magnet, which must have like poles on either face. However, the steel balls repel each other because they have like poles facing each other.

