Pearson Physics Level 30
Unit VI Forces and Fields: Unit VI Review Solutions

Student Book pages 626–631

Vocabulary

1. ampere: the flow of 1 C of charge past a point in a conductor in 1 s
charge migration: movement of electrons in a neutral object where one side of the object becomes positive and the other side becomes negative; caused by induction
charge shift: movement of electrons in an atom where one side of an atom becomes positive and the other side becomes negative; caused by induction
charging by induction: process of charging an object by first polarizing it by induction and then retaining the charge by grounding
commutator: a mechanism for maintaining a properly polarized connection to the moving coil in a motor or generator; a split metal ring
conduction: process of charging an object through the direct transfer of electrons when a charged object touches a neutral object
conductor: material in which electrons in the outermost regions of the atom are free to move
coulomb (C): the SI unit for electric charge, equivalent to the charge on 6.25×10^{18} electrons or protons
Coulomb's law: magnitude of the force of electrostatic attraction or repulsion ($|\vec{F}_e|$) is:
• directly proportional to the product of the two charges q_1 and q_2:

$$\left|\vec{F}_e\right| \propto q_1q_2$$

• inversely proportional to the square of the distance between their centres r:

$$\left|\vec{F}_e\right| \propto \frac{1}{r^2}$$

If these are the only variables that determine the electrostatic force, then:

$$\left|\vec{F}_e\right| \propto \frac{q_1q_2}{r^2}$$

current: quantity of charge that flows through a wire in a given unit of time
domain: a region of material in which the magnetic fields of most of the atoms are aligned
electric field line: line representing the electric field around a charge or charges; each line shows direction; the density of the lines indicates the magnitude of the electric field
electric potential: the electric potential energy stored per unit charge at a given point in an electric field; symbol is V
electric potential difference: change in electric potential experienced by a charge moving between two points in an electric field
electric potential energy: energy stored in a system of two charges a certain distance apart

electromagnet: a magnet having its magnetic field produced by electric current flowing through a coil of wire
electromagnetic induction: production of electricity by magnetism
electron volt: the change in energy of an electron when it moves through a potential difference of 1 V
electrostatics: study of electric charges at rest
ferromagnetic: having magnetic properties, like those of iron
field: a three-dimensional region of influence surrounding an object
generator effect (electromagnetic induction): production of an electric current by moving a conductor through a magnetic field
grounding: the process of transferring charge to and from Earth
induction: movement of charge caused by an external charged object
insulator: material in which the electrons are tightly bound to the nucleus and are not free to move within the substance
law of conservation of charge: the net charge of an isolated system is conserved
law of magnetism: like magnetic ends repel and unlike ends attract each other
Lenz's law: the direction of a magnetically induced current is such as to oppose the cause of the current
magnetic field: a three-dimensional region of magnetic influence surrounding a magnet, in which other magnets are affected by magnetic forces
motor effect force: the deflecting force acting on a charged particle moving in a magnetic field
net charge: the sum of all electric charges in the system
plasma: highly ionized gas containing nearly equal numbers of free electrons and positive ions
semiconductor: a material that is a good conductor in certain situations, and a good insulator in other situations
solenoid: an electromagnet that operates a mechanical device
source charge: charge that produces an electric field
superconductor: a conductor that has no measurable resistance at very low temperatures
test charge: charge with a magnitude small enough that it does not disturb the charge on the source charge and thus change its electric field

Knowledge

Chapter 10

2. The atoms of silver do not hold onto their outer electrons as tightly as atoms of rubber do. Therefore, silver has more "free" electrons, which makes the silver a better conductor than rubber.

3. Materials that are superconductors can transmit current with no measurable resistance, and therefore no measurable loss of energy to heat. Using these materials in technology increases the efficiency of all components operating on electrical energy.

4. This method of charging objects is called charging by induction with the grounding step. The final charge on the metal ball is a net positive charge.

5. (a) A similarity between the two procedures is that both involve contact between two objects. A difference is that charging by friction involves more surface contact between the two objects.

(b) During induction, a charge shift occurs when electrons merely move to the other side of their atoms in an insulator, thus polarizing the atoms. A charge migration occurs when electrons move to the other side of a conductor, thus polarizing the conductor.

6. (a) The ebonite will be negative and the fur will be positive. This procedure is charging by friction. When the rod is held near the sphere, the sphere becomes polarized. This method is charging by induction.

(b) The glass rod will be positive, the silk will be negative, and the sphere will be positive. In the rubbing process, the rod and the silk become charged by friction. When the rod touches the sphere, the sphere becomes similarly positively charged by conduction.

7. The other object must have an equal but net positive charge, according to the law of conservation of charges. The net charge of the system is zero because no charges have been created.

8. (a) $\vec{F}_e \propto q_1 q_2$

(b) $\vec{F}_e \propto \frac{1}{r^2}$

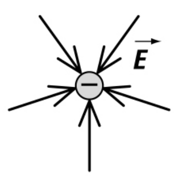
(c) $\vec{F}_e$ is attractive if both charges are different, and it is repulsive if both charges are the same.

Chapter 11

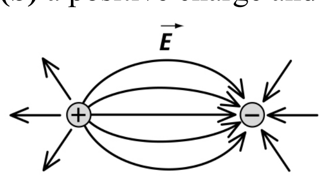
9. The net vector field at a point is equal to the vector sum of individual vectors acting at the point.

10. The test charge must be small enough so that it does not disturb the position of any other charge in the system.

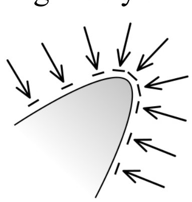
11. (a) a negative point charge



(b) a positive charge and a negative point charge in the same region



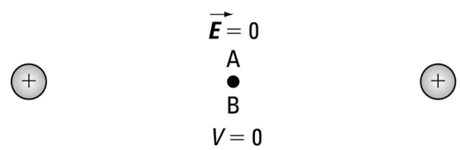
(c) a negatively charged cone-shaped object



12. At any point within a charged object, the vector sum of the electric fields acting at that point will always equal zero.

13. If an object becomes charged, repulsive electrostatic forces cause the charges to accumulate on the outside surface of the object. The vector sum of electric fields within the object is always zero, so the interior of the object is shielded from any net electric field. There is never any net charge or electric field within a conducting object. The same effect is impossible with gravitational fields because gravitational forces can never be repulsive.

14.



15. The zero reference point for electric potential energy around any charge is chosen at infinity. For all charges, the values of the electric potential energy may be positive or negative, depending on the type of charge placed in the field. However, the values of the electric potential energy decrease as distance from the charge increases.

16. If the distance between the plates decreases, then the value of the electric field must increase, because $\left|\vec{E}\right| \propto \frac{1}{d}$.

17. (a) The magnitude of the electric field would be $\left|\vec{E}\right| = k\frac{q_1}{r^2}$, and the direction is away from the positive charge.

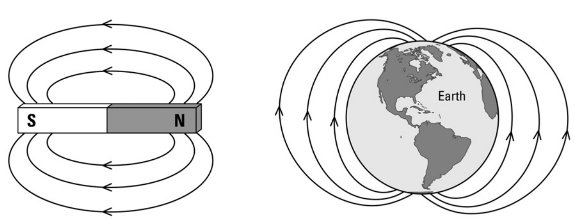
(b) The electric potential energy of another charge placed at this point is equal to the work done to move the charge against the electric field to this point: $\Delta E_p = W$.

(c) The electric potential at this point depends on how much electric potential energy is stored per unit charge: $V = \frac{\Delta E_p}{q}$.

18. The electric potential energy of a charge at a point in an electric field is equal to the work done to move the charge against the electric field to this point: $\Delta E_p = W$. This relationship is governed by the law of conservation of energy.

Chapter 12

19.



(a) Similarities: Both consist of magnetic field lines. The magnitude of the magnetic fields decreases with distance from the magnets.

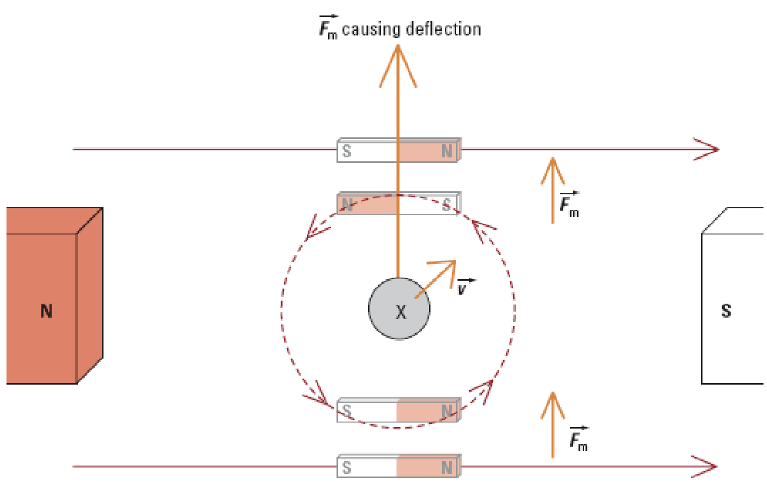
(b) Differences: In a bar magnet, the magnetic field lines run from the north pole to the south pole, whereas on Earth, the magnetic field lines run from the geographical south pole to the geographical north pole. Students may also add that the magnetic field lines around a bar magnet form similar patterns on either side, whereas on Earth, the magnetic field lines are compressed on the side facing the Sun and stretched out on the side away from the Sun.

20. Magnetic effects are caused by domains, which have a north and a south region on either side or end. As long as there are two sides or ends, there must be two poles. This property is similar to a coin. It must have a head and a tail. One pole cannot exist by itself.

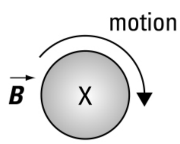
21. Two simple demonstration techniques to outline the magnetic field surrounding a magnet are sprinkling iron filings around the magnet and placing compasses around the magnet.

22. A charge moving perpendicular to a magnetic field will experience a force causing it to follow a circular path. This motion is accelerated motion in which the direction is always changing but the magnitude of the motion remains constant. In order for the magnitude of the motion to increase, the force must be in the same direction as the motion of the charge.

23. In the diagram below, the charge experiencing the deflecting force is negative.



24. The direction of the magnetic field is downward, into the paper.



25. The magnetic field around the dart is in the shape of concentric circles around the dart and its direction is counterclockwise.

26. The magnetic force depends on the amount of charge, the speed of the charge perpendicular to the magnetic field, and the magnitude of the external magnetic field.

27. Both effects involve an external magnetic field and a moving charge within this magnetic field. However, the principle of the motor effect is that electricity produces magnetism, and the principle of the generator effect is that magnetism produces electricity.

28. (a) In a motor, a current must be supplied to provide the magnetic force to rotate the loop of wire. As the loop of wire rotates, it cuts magnetic field lines. This effect generates a current in the opposite direction to the supplied current, which inhibits the operation of the motor, as predicted by Lenz's law.

(b) In a generator, a force must be applied to rotate a loop of wire through an external magnetic field, thus generating a current in the loop. However, as the generated current flows through the loop, it creates a magnetic force, which opposes the original force supplied to rotate the loop. This inhibits the operation of the generator, as predicted by Lenz's law.

Applications

29. The negative charges on the conductor will distribute equally on the outside surface of the conductor due to the electrostatic repulsive forces. The negative charges on the insulator will remain on the outside surface of the insulator at the point of contact.

30. As water molecules in the clouds collide, a transfer of electrons occurs. Some droplets become negatively charged, whereas others are positively charged through this process of charging by friction. The positive water vapour molecules rise to the top of the cloud, and the negative water vapour molecules condense into water droplets and drop to the bottom of the cloud. The negatively charged bottom of the cloud then causes charge migration on Earth's surface and the part of the surface closest to the cloud becomes positively charged by induction. When a streamer from the surface meets a leader from the clouds, a lightning discharge occurs, sending negative charges to the surface through this path. This is a type of charging by conduction.

31. (a) To charge a neutral electroscope positively using a negatively charged rod, you must use the process of charging by induction with the grounding step.

(b) To charge a neutral electroscope negatively using a negatively charged rod, you must use the process of charging by conduction.

32. As the rod is brought near the thread, electrons in the thread are repelled to the other side of the atoms. This process is charge shift due to induction. The atoms of the thread are now polarized. Attraction between the negative rod and the positive side of the atoms is greater than repulsion of the negative rod and the negative electrons. Attraction occurs, and the rod attracts the thread. Upon contact, electrons from the rod transfer to the thread, charging the thread negatively by contact. Both the thread and the rod are negatively charged, so repulsion occurs.

33. (a) You are being charged by conduction because you are actually touching the sphere.

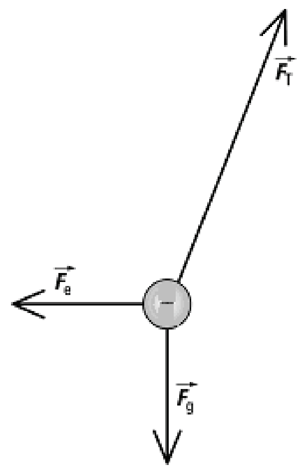
(b) Yes, however, the charge will flow through you to the ground as a shock.

34. (a) As the rod is brought near the ball, electrons in the ball are repelled to the other side of the atoms. This is charge shift due to induction. The atoms of the ball are now polarized. Attraction between the negative rod and the positive side of the atoms is greater than repulsion of the negative rod and the negative electrons. The rod attracts the ball.

(b) On contact, electrons from the rod transfer to the ball, charging the ball negatively by contact. Both the ball and the rod are negatively charged, and repulsion occurs.

35. The compass will deflect counterclockwise and point in a westward direction, as defined by the left-hand wire grasp rule.

36. (a)



(b) The force that balances the gravitational force is the vertical component of the tension force. The force that balances the electrostatic force is the horizontal component of the tension force.

37. Selenium is a semiconductor that becomes a conductor when exposed to light and an insulator in the dark. This property is essential in the operation of a photocopier.

38. Charge shift occurs in an insulator when electrons merely move to the other side of each atom, thus causing the atoms to become polarized. Charge migration occurs in a conductor when electrons transfer to the other side of the conductor, thus causing the conductor to become polarized.

39. ***Given***

(a) $\Delta V = 0.70$ V

$\Delta d = 5.0 \times 10^{-9}$ m

$q = +1.6 \times 10^{-19}$ C

Required

(a) magnitude of the electric field between the outside and the inside of the membrane $\left(\left|\vec{E}\right|\right)$

(b) the amount of work necessary to move the sodium ion (W)

Analysis and Solution

(a) To calculate the magnitude of the electric field, use:

$$\begin{aligned}\left|\vec{E}\right| &= \frac{\Delta V}{\Delta d} \\ &= \frac{0.70\ \text{V}}{5.0 \times 10^{-9}\ \text{m}} \\ &= 1.4 \times 10^{8}\ \text{V/m}\end{aligned}$$

(b) In a conservative system, $\Delta E_p = W$.

To calculate the electric potential energy, use the equation $V = \frac{\Delta E_p}{q}$.

$$\begin{aligned}\Delta E_p &= Vq \\ &= (0.70\ \text{V})(1.6 \times 10^{-19}\ \text{C}) \\ &= 1.1 \times 10^{-19}\ \text{J}\end{aligned}$$

Paraphrase

(a) The magnitude of the electric field between the outside and the inside of the membrane is 1.4×10^8 V/m.

(b) The work necessary to move the sodium ion is 1.1×10^{-19} J.

40.

	Similarities	Differences
Newton's law of universal gravitation	The gravitational force:	
	varies with $\frac{1}{r^2}$; acts at a distance.	is much smaller than the electrostatic force; can only be attractive.
Coulomb's law of electrostatics	The electrostatic force:	
	varies with $\frac{1}{r^2}$; acts at a distance.	is much larger than the gravitational force; can be attractive or repulsive.

41. ***Given***

$q_1 = -1.60 \times 10^{-19}$ C

$q_2 = -1.60 \times 10^{-19}$ C

$|\vec{F}_e| = 3.50 \times 10^{-11}$ N

Required

the distance between the two electrons (r)

Analysis and Solution

To calculate the distance, use:

$$|\vec{F}_e| = k\frac{q_1 q_2}{r^2}$$

$$\begin{aligned} r &= \sqrt{\frac{kq_1q_2}{|\vec{F}_e|}} \\ &= \sqrt{\frac{\left(8.99 \times 10^9 \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)(1.60 \times 10^{-19}\ \text{C})(1.60 \times 10^{-19}\ \text{C})}{(3.50 \times 10^{-11}\ \text{N})}} \\ &= 2.56 \times 10^{-9}\ \text{m} \end{aligned}$$

Paraphrase

The distance between the two electrons is 2.56×10^{-9} m.

42. ***Given***

$q = -3.00 \times 10^{-2}$ C

$r = 0.200$ m

Required

electrostatic force acting on the two spheres after they touch ($\vec{F}_e$)

Analysis and Solution

When the two spheres touched, the charge was equally divided between them, so each sphere now has a charge of -1.50×10^{-2} C.

According to Newton's third law, the electrostatic forces exerted by the two charges on each other are the same in magnitude but opposite in direction. Thus, it is only necessary to calculate the magnitude of the forces.

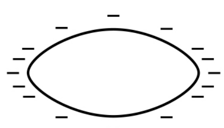
To calculate the magnitude of the electrostatic force between two charges, use:

$$\begin{aligned}|\vec{F}_e| &= k\frac{q_1q_2}{r^2} \\ &= \frac{\left(8.99\times10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)(1.50\times10^{-2}\ \text{C})(1.50\times10^{-2}\ \text{C})}{(0.200\ \text{m})^2} \\ &= 5.06\times10^7\ \text{N}\end{aligned}$$

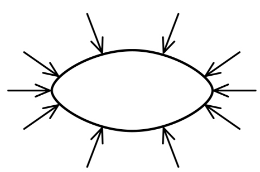
Paraphrase

The magnitude of the electrostatic force acting on the two spheres is 5.06×10^7 N. Since both charges are negative, the electrostatic force is repulsive.

43. (a)



(b)



(c) The intensity of the electric field will be greatest at the points of the football-shaped object.

(d) The intensity of the electric field is greatest at the point of the lightning rod compared to other surfaces on Earth. The electric charges from the clouds will move to the region with the greatest electric field intensity — the lightning rod.

44. (a) As the car is travelling along the surface of Earth, its antenna, which is a conductor, is cutting the magnetic field lines of Earth, which run parallel to the surface of Earth. A voltage is produced in the antenna, which in turn induces a current in the antenna, as a result of the generator effect.

(b) Since magnetic north is at the south pole and the car travels east, the direction of the current in the antenna is downward.

45. To determine the strength of the electric field, use:

$$\begin{aligned}|\vec{E}| &= \frac{|\vec{F}_e|}{q_2} \\ &= \frac{3.0\times10^{-5}\ \text{N}}{2.0\times10^{-6}\ \text{C}} \\ &= 15\ \text{N/C}\end{aligned}$$

The strength of the electric field is 15 N/C.

46. ***Given***

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

$\Delta V = 2.0 \times 10^4$ V

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

Required

kinetic energy gained by the proton (E_{k_f})

maximum speed of the proton at the negative plate (v)

Analysis and Solution

The initial electric potential energy of the proton at the positive plate is: $E_{p_i} = Vq$

Since it is at rest, its initial kinetic energy is: $E_{k_i} = 0$ J

The final electric potential energy of the proton at the negative plate is: $E_{p_f} = 0$ J

Since this is a conservative system, a loss of electric potential energy is converted to a gain of kinetic energy, according to the law of conservation of energy:

$$E_{p_i} + E_{k_i} = E_{p_f} + E_{k_f}$$

$$Vq + 0 \text{ J} = 0 \text{ J} + E_{k_f}$$

$$\begin{aligned} E_{k_f} &= Vq \\ &= \left(2.0 \times 10^4 \text{ V}\right)\left(1.60 \times 10^{-19} \text{ C}\right) \\ &= 3.2 \times 10^{-15} \text{ J} \end{aligned}$$

To solve for the speed of the proton, use:

$$E_k = \frac{1}{2}mv^2$$

$$\begin{aligned} v &= \sqrt{\frac{2E_k}{m}} \\ &= \sqrt{\frac{2\left(3.2 \times 10^{-15} \text{ J}\right)}{1.67 \times 10^{-27} \text{ kg}}} \\ &= 2.0 \times 10^6 \text{ m/s} \end{aligned}$$

Paraphrase

The kinetic energy gained by the proton is 3.2×10^{-15} J and its maximum speed at the negative plate is 2.0×10^6 m/s.

47. ***Given***

$q_1 = +4.00 \times 10^{-6}$ C

$q_2 = +3.00 \times 10^{-6}$ C

$q_3 = -2.00 \times 10^{-6}$ C

$r_{q_1 \text{ to } q_2} = 0.500$ m

Required

position of the third charge so that the net electrostatic force on it is zero ($r_{q_3 \text{ to } q_1}$)

Analysis and Solution

The distance of q_3 from q_1 is $r_{q_3 \text{ to } q_1}$.

The distance of q_2 from q_3 is ($0.500 \text{ m} - r_{q_3 \text{ to } q_1}$).

The electrostatic force of q_1 on q_3 is an attractive force to the left and is a negative vector quantity: $\vec{F}_{1-2}$.

The electrostatic force of q_2 on q_3 is an attractive force to the right and is a positive vector quantity: $\vec{F}_{3-2}$.

The negative and the positive signs for the charges are used only to determine if the electrostatic force is attractive or repulsive.

Since the two electrostatic forces are force vectors along the same line, the net force can be determined by adding the vectors. Consider to the right of the first charge to be positive.

$$\left|\vec{F}_{\text{net}}\right| = \left|\vec{F}_{1-3}\right| + \left|\vec{F}_{3-2}\right|$$

$$0 = -\frac{\left(8.99\times10^{9}\ \frac{\text{N}\cdot\text{m}^2}{\cancel{\text{C}^2}}\right)(4.00\times10^{-6}\ \cancel{\text{C}})(2.00\times10^{-6}\ \cancel{\text{C}})}{(r_{q_3\text{ to }q_1})^2} + \frac{\left(8.99\times10^{9}\ \frac{\text{N}\cdot\text{m}^2}{\cancel{\text{C}^2}}\right)(3.00\times10^{-6}\ \cancel{\text{C}})(2.00\times10^{-6}\ \cancel{\text{C}})}{(0.500\ \text{m}-r_{q_3\text{ to }q_1})^2}$$

$$r_{q_3\text{ to }q_1} = 0.268\ \text{m}$$

Paraphrase

The net electrostatic force on the third charge is 0 N when it is placed 0.268 m to the right of the first charge.

48. To calculate the magnitude of the charge, use:

$$V = \frac{\Delta E_{\text{p}}}{q}$$

$$\begin{aligned} q &= \frac{\Delta E_{\text{p}}}{V} \\ &= \frac{1.24\ \text{J}}{2.5\times10^{4}\ \text{V}} \\ &= 5.0\times10^{-5}\ \text{C} \end{aligned}$$

The magnitude of the charge is 5.0×10^{-5} C.

49. ***Given***

$l = 0.30$ m

$\left|\vec{B}\right| = 0.50$ T

$\left|\vec{F}_{\text{m}}\right| = 0.11$ N

Required

current in the wire (I)

Analysis and Solution

To determine the current in the wire, use the equation:

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

$$\begin{aligned} I &= \frac{\left|\vec{F}_{\text{m}}\right|}{l_{\perp}\left|\vec{B}\right|} \\ &= \frac{0.11\ \text{N}}{(0.30\ \text{m})(0.50\ \text{T})} \\ &= 0.73\ \text{A} \end{aligned}$$

Paraphrase
The current in the wire is 0.73 A.

50. ***Given***

$q_1 = +3.0 \times 10^{-6}$ C

$q_2 = -1.5 \times 10^{-5}$ C

$r_{q_1 \text{ to } q_2} = 0.50$ m

Required

(a) net electric field at a point midway between the two charges ($\vec{E}_{\text{net}}$)

(b) the electrostatic force acting on the two charges ($\vec{F}_{\text{e}}$)

Analysis and Solution

(a) The electric field created by q_1 at point P, midway between the two charges, is to the left.
The electric field created by q_2 at point P, midway between the two charges, is to the left.
The distance between each charge and point P is:

$$\begin{aligned} r &= \frac{0.50 \text{ m}}{2} \\ &= 0.25 \text{ m} \end{aligned}$$

Since the two electric field vectors are along the same line, the net electric field can be determined by adding the individual field vectors.

$$\vec{E}_{\text{net}} = \vec{E}_{q_1} + \vec{E}_{q_2}$$

Consider left to be positive.

$$\begin{aligned} E_{\text{net}} &= E_{q_1} + E_{q_2} \\ &= \left(\frac{kq_1}{r^2_{\text{P to } q_1}}\right) + \left(\frac{kq_2}{r^2_{\text{P to } q_2}}\right) \\ &= \frac{\left(8.99 \times 10^9 \frac{\text{N} \cdot \cancel{\text{m}^2}}{\text{C}^{\cancel{2}}}\right)(3.0 \times 10^{-6} \cancel{\text{C}})}{(0.25 \cancel{\text{m}})^2} + \frac{\left(8.99 \times 10^9 \frac{\text{N} \cdot \cancel{\text{m}^2}}{\text{C}^{\cancel{2}}}\right)(1.5 \times 10^{-5} \cancel{\text{C}})}{(0.25 \cancel{\text{m}})^2} \\ &= 4.32 \times 10^5 \text{ N/C} + 2.16 \times 10^6 \text{ N/C} \\ &= 2.6 \times 10^6 \text{ N/C} \end{aligned}$$

(b) According to Newton's third law, the electrostatic forces exerted by the two charges on each other are the same in magnitude but opposite in direction. Thus, it is only necessary to calculate the magnitudes of the forces.
To calculate the magnitude of the electrostatic force acting on the two charges, use:

$$\begin{aligned} \left|\vec{F}_{\text{e}}\right| &= k\frac{q_1 q_2}{r^2} \\ &= \frac{\left(8.99 \times 10^9 \frac{\text{N} \cdot \cancel{\text{m}^2}}{\cancel{\text{C}^2}}\right)(3.0 \times 10^{-6} \cancel{\text{C}})(1.5 \times 10^{-5} \cancel{\text{C}})}{(0.50 \cancel{\text{m}})^2} \\ &= 1.6 \text{ N} \end{aligned}$$

The charges are opposite, so the force is attractive.

Paraphrase

(a) The net electric field at a point midway between the two charges is 2.6×10^6 N/C [left].

(b) The electrostatic force acting on the two charges is 1.6 N. Since one charge is negative and the other is positive, the electrostatic force is attractive.

51. (a) The ball of the generator acquires a negative charge as the belt of the generator rubs against the metal combs in the generator. Electron transfer occurs between the belt and the comb, and the electrons accumulate on the outside surface of the ball. This process is charging by friction.

(b) When you touch the ball, the charge transfers to you as a shock. This process is charging by conduction.

(c) The shaft of the wire is a pointed surface. Charges tend to accumulate at a point and then the electrons leak into the air and ionize air molecules. This process is the same as a lightning rod. The shaft of wire drains the charges from the ball of the generator, thus you will not feel a shock when you touch the ball.

(d) As the plane travels through Earth's magnetic field, a current is generated by the metal wings, which are conductors. To prevent a dangerous charge buildup, the metal strips drain the charge into the air, similar to the metal wire on the generator in part (c) above.

52. ***Given***

$m = 0.015$ kg

$q_1 = 1.5 \times 10^{-8}$ C

$q_2 = 2.5 \times 10^{-8}$ C

$r = 1.0 \text{ cm} = 0.010$ m

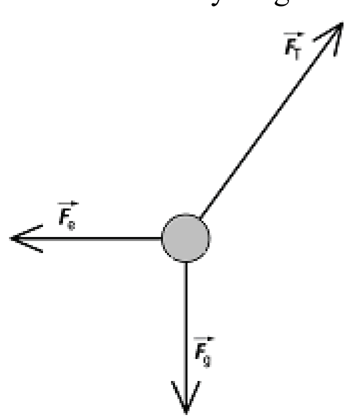
Required

a free-body diagram showing all the forces

magnitude of the electrostatic force of repulsion acting on the two charges ($|\vec{F}_e|$)

Analysis and Solution

Draw a free-body diagram of the forces and distances.

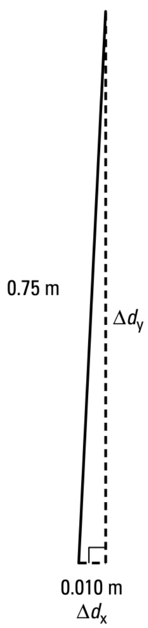


According to Newton's third law, the electrostatic forces exerted by the two charges on each other are the same in magnitude but opposite in direction. Thus, it is only necessary to calculate the magnitude of the forces.

Determine the force of gravitational attraction on the mass:

$$\left|\vec{F}_{\text{g}}\right| = mg$$
$$= (0.015 \text{ kg})(9.81 \text{ N/kg})$$
$$= 0.147 \text{ N}$$

Determine the magnitude of Δd_y:



$$\Delta d_y = \sqrt{(0.75 \text{ m})^2 - (0.010 \text{ m})^2}$$
$$= 0.75 \text{ m}$$

Determine the electrostatic force on the two charges, using the free-body diagram:

$$\frac{\left|\vec{F}_{\text{e}}\right|}{\left|\vec{F}_{\text{g}}\right|} = \frac{\Delta d_x}{\Delta d_y}$$

$$\left|\vec{F}_{\text{e}}\right| = \frac{\left|\vec{F}_{\text{g}}\right| \Delta d_x}{\Delta d_y}$$
$$= \frac{(0.147 \text{ N})(0.010 \not{\text{m}})}{(0.75 \not{\text{m}})}$$
$$= 2.0 \times 10^{-3} \text{ N}$$

Paraphrase

The magnitude of the repulsive electrostatic force acting on the two charges is 2.0×10^{-3} N.

53. ***Given***

$\left|\vec{E}\right| = 3.00 \times 10^6$ N/C

$\Delta V = 500$ V

Required

minimum distance between the charged plates (Δd)

Analysis and Solution

To calculate the minimum distance between the plates, use:

$$\left|\vec{E}\right| = \frac{\Delta V}{\Delta d}$$

$$\begin{aligned}\Delta d &= \frac{\Delta V}{\left|\vec{E}\right|} \\ &= \frac{500 \text{ V}}{3.00 \times 10^{6} \text{ N/C}} \\ &= 1.67 \times 10^{-4} \text{ m}\end{aligned}$$

Paraphrase

The minimum distance between the charged plates is 1.67×10^{-4} m.

54. ***Given***

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

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

$r = 5.29 \times 10^{-11}$ m

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

$m_{p^+} = 1.67 \times 10^{-27}$ kg

Required

(a) magnitude of the gravitational force of attraction between the two masses ($\left|\vec{F}_g\right|$)

(b) magnitude of the electrical force of attraction between the two charges ($\left|\vec{F}_e\right|$)

(c) how much greater the electrical force is than the gravitational force $\left(\frac{\left|\vec{F}_e\right|}{\left|\vec{F}_g\right|}\right)$

Analysis and Solution

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

$$\begin{aligned}\left|\vec{F}_g\right| &= G\frac{m_{e^-} m_{p^+}}{r^2} \\ &= \frac{\left(6.67 \times 10^{-11} \frac{\text{N} \cdot \cancel{\text{m}^2}}{\cancel{\text{kg}^2}}\right)(9.11 \times 10^{-31} \cancel{\text{kg}})(1.67 \times 10^{-27} \cancel{\text{kg}})}{(5.29 \times 10^{-11} \cancel{\text{m}})^2} \\ &= 3.63 \times 10^{-47} \text{ N}\end{aligned}$$

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

$$\begin{aligned}\left|\vec{F}_e\right| &= k\frac{q_{e^-} q_{p^+}}{r^2} \\ &= \frac{\left(8.99 \times 10^{9} \frac{\text{N} \cdot \cancel{\text{m}^2}}{\cancel{\text{C}^2}}\right)(1.60 \times 10^{-19} \cancel{\text{C}})(1.60 \times 10^{-19} \cancel{\text{C}})}{(5.29 \times 10^{-11} \cancel{\text{m}})^2} \\ &= 8.22 \times 10^{-8} \text{ N}\end{aligned}$$

(c) The ratio of the electrostatic force to the gravitational force is:

$$\frac{\left|\vec{F}_e\right|}{\left|\vec{F}_g\right|} = \frac{8.22 \times 10^{-8} \cancel{N}}{3.63 \times 10^{-47} \cancel{N}}$$
$$= 2.27 \times 10^{39}$$

Paraphrase

(a) The gravitational force of attraction between the two masses is 3.63×10^{-47} N.
(b) The electrical force of attraction between the two charges is 8.22×10^{-8} N.
(c) The electrical force is 2.27×10^{39} times greater than the gravitational force.

55. (a) The alpha particle and the proton are positively charged and deflect in a circular arc in one direction, whereas the electron is negatively charged and deflects in a circular arc in the other direction, as determined by the right- and left-hand rules, respectively. Since the alpha particle has twice the charge, there is twice the force causing it to deflect. The alpha particle also has almost four times the mass of the proton, so the alpha particle will deflect in a larger arc than the proton, from the equation $r = \frac{mv}{q\left|\vec{B}\right|}$.

(b) The alpha particle and the proton deflect in a parabolic arc, eventually travelling in the direction of the electric field, whereas the electron will deflect in a parabolic arc, eventually travelling against the direction of the electric field.

(c) All three charges will deflect in a parabolic arc, eventually travelling in the direction of the gravitational field.

56. (a) Rub the ebonite rod with the fur. The rod will now be negatively charged. If the rod touches the electroscope, electron transfer occurs, and the electroscope is now negatively charged by conduction.

(b) Rub the glass rod with silk. The rod is now positively charged. If this rod is held near a neutral electroscope, electrons in the electroscope are attracted to the ball of the electroscope, and the leaves diverge with a positive charge. Grounding the electroscope moves electrons into the scope from the ground to neutralize the apparent surplus of positive charge on the leaves. When the ground is removed and then the rod, the electroscope will have a residual negative charge by induction.

57. ***Given***

$m = 2.00 \times 10^{-26}$ kg

$\vec{B} = 2.00 \times 10^{-4}$ T [N]

$q = 6.40 \times 10^{-19}$ C

Required

speed (v) at which the magnitudes of the magnetic force and the gravitational force are equal
charge of the particle

Analysis and Solution

The gravitational force on the charge has a magnitude of $\left|\vec{F}_g\right| = mg$ and is directed downward.
The magnetic force on the charge has a magnitude of $\left|\vec{F}_m\right| = qv_\perp\left|\vec{B}\right|$ and must be directed upward.

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

But the magnetic deflecting force and the gravitational force balance, so $\left|\vec{F}_{\text{net}}\right| = 0$.

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

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

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

$$= \frac{(2.00\times10^{-26}\ \cancel{\text{kg}})\left(9.81\ \frac{\text{N}}{\cancel{\text{kg}}}\right)}{(2.00\times10^{-4}\ \text{T})(6.40\times10^{-19}\ \text{C})}$$

$$= 1.53\times10^{-3}\ \text{m/s}$$

If the magnetic force is upward, the direction of the magnetic field is northward, and the direction of the motion of the charge is east, then the charge on the particle must be positive, according to the right-hand rule.

Paraphrase

The positive charge will travel in a straight line if its speed is 1.53×10^{-3} m/s.

58. ***Given***

$q = 3.20\times10^{-19}\ \text{C}$

$\left|\vec{B}\right| = 3.30\ \text{T}$

$v_{\perp} = 3.00\times10^{6}\ \text{m/s}$

$m = 6.65\times10^{-27}\ \text{kg}$

Required

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

(b) radius of the deflecting arc (r)

Analysis and Solution

(a) Determine the magnitude of the deflecting force:

$$\left|\vec{F}_{\text{m}}\right| = qv_{\perp}\left|\vec{B}\right|$$

$$= (3.20\times10^{-19}\ \text{C})(3.00\times10^{6}\ \text{m/s})(3.30\ \text{T})$$

$$= 3.17\times10^{-12}\ \text{N}$$

(b) The magnetic force on the helium ion has a magnitude of $\left|\vec{F}_{\text{m}}\right| = qv_{\perp}\left|\vec{B}\right|$ and it is the centripetal force causing the alpha particle to deflect in a circular arc.

Since $\left|\vec{F}_{\text{m}}\right| = \left|\vec{F}_{\text{c}}\right|$, where $\left|\vec{F}_{\text{c}}\right| = \frac{mv^2}{r}$,

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

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

$$= \frac{(6.65 \times 10^{-27}\ \text{kg})(3.00 \times 10^{6}\ \text{m/s})}{(3.20 \times 10^{-19}\ \text{C})(3.30\ \text{T})}$$

$$= 1.89 \times 10^{-2}\ \text{m}$$

Paraphrase

(a) The magnitude of the deflecting force on the helium ion is 3.17×10^{-12} N.

(b) The helium ion will deflect in a circular arc with a radius of 1.89×10^{-2} m.

59. ***Given***

$q_A = +3.50 \times 10^{-6}$ C

$q_B = -2.44 \times 10^{-6}$ C

$q_C = +1.00 \times 10^{-6}$ C

$r_{AB} = 4.35$ cm $= 0.0435$ m

Required

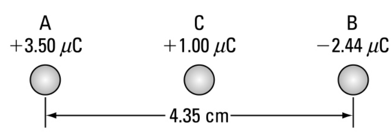
(a) net electrostatic force on sphere C midway between charges A and B ($\vec{F}_{net}$)

(b) net electrostatic force on sphere C 2.50 cm right of charge B ($\vec{F}_{net}$)

(c) net electrostatic force on sphere C 2.50 cm down from charge B ($\vec{F}_{net}$)

Analysis and Solution

(a)



The distance from q_A to q_C is:

$$r_{AC} = \frac{0.0435}{2}$$

$$= 0.02175\ \text{m}$$

So the distance from q_B to q_C is:

$r_{BC} = 0.02175$ m

The electrostatic force of q_A on q_C is a repulsive force to the right, and is a positive vector quantity: $\vec{F}_{AC}$.

The electrostatic force of q_B on q_C is an attractive force to the right, and is a positive vector quantity: $\vec{F}_{BC}$.

The negative and the positive signs for the charges are used only to determine if the electrostatic force is attractive or repulsive.

Since the two electrostatic forces are force vectors along the same line, the net force can be determined by adding the vectors.

$$\vec{F}_{net} = \vec{F}_{AC} + \vec{F}_{BC}$$

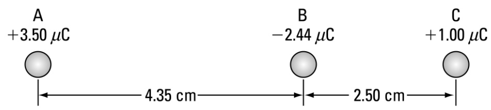
$$|\vec{F}_{net}| = |\vec{F}_{AC}| + |\vec{F}_{BC}|$$

$$= \frac{\left(8.99 \times 10^9 \ \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}\right)(3.50 \times 10^{-6}\ \text{C})(1.00 \times 10^{-6}\ \text{C})}{(0.02175\ \text{m})^2} + \frac{\left(8.99 \times 10^9 \ \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}\right)(2.44 \times 10^{-6}\ \text{C})(1.00 \times 10^{-6}\ \text{C})}{(0.02175\ \text{m})^2}$$

$= 66.51\ \text{N} + 46.37\ \text{N}$

$= 113\ \text{N}$

(b)



$r_{AC} = 0.0435\ \text{m} + 0.0250\ \text{m}$

$= 0.0685\ \text{m}$

$r_{BC} = 0.0250\ \text{m}$

The electrostatic force of q_A on q_C is a repulsive force to the right, and is a positive vector quantity: $\vec{F}_{AC}$.

The electrostatic force of q_B on q_C is an attractive force to the left, and is a negative vector quantity: $\vec{F}_{BC}$.

The negative and the positive signs for the charges are only used to determine if the electrostatic force is attractive or repulsive.

Since the two electrostatic forces are force vectors along the same line, the net force can be determined by adding the vectors. Consider right to be positive.

$\vec{F}_{net} = \vec{F}_{AC} + \vec{F}_{BC}$

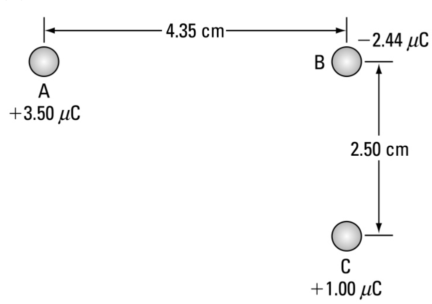
$$|\vec{F}_{net}| = |\vec{F}_{AC}| - |\vec{F}_{BC}|$$

$$= \frac{\left(8.99 \times 10^9 \ \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}\right)(3.50 \times 10^{-6}\ \text{C})(1.00 \times 10^{-6}\ \text{C})}{(0.0685\ \text{m})^2} - \frac{\left(8.99 \times 10^9 \ \frac{\text{N} \cdot \text{m}^2}{\text{C}^2}\right)(2.44 \times 10^{-6}\ \text{C})(1.00 \times 10^{-6}\ \text{C})}{(0.0250\ \text{m})^2}$$

$= 6.706\ \text{N} - 35.10\ \text{N}$

$= -28.4\ \text{N}$

(c)



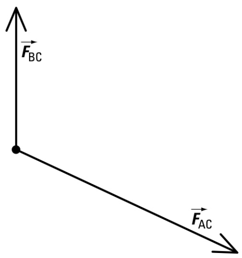
The electrostatic force of q_A on q_C is a repulsive force ($\vec{F}_{AC}$) on a line from charge A away from charge C.

The electrostatic force of q_B on q_C is an attractive force ($\vec{F}_{BC}$) directly up from charge C toward charge B.

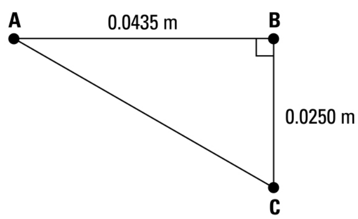
The negative and the positive signs for the charges are used only to determine if the electrostatic force is attractive or repulsive.

Since the two electrostatic forces on charge C are force vectors that are at an angle, use the component method to determine the net force.

Draw a free body diagram of the electrostatic forces on charge C:



Determine the distance between charges A and C by using the Pythagorean theorem:



$$r_{AC} = \sqrt{(0.0435\ \text{m})^2 + (0.0250\ \text{m})^2}$$
$$= 0.05017\ \text{m}$$

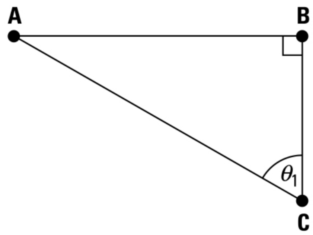
Determine the electrostatic force of charge A on charge C (repulsion away from A):

$$\left|\vec{F}_{AC}\right| = k\frac{q_A q_C}{{r_{AC}}^2}$$
$$= \frac{\left(8.99 \times 10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)(3.50\times10^{-6}\ \text{C})(1.00\times10^{-6}\ \text{C})}{(5.017\times10^{-2}\ \text{m})^2}$$
$$= 12.50\ \text{N}$$

Determine the electrostatic force of charge B on charge C (attraction toward B):

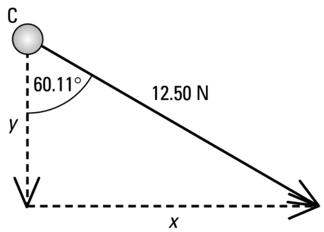
$$\left|\vec{F}_{BC}\right| = k\frac{q_B q_C}{r_{BC}^2}$$
$$= \frac{\left(8.99 \times 10^9\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)(2.44\times10^{-6}\ \text{C})(1.00\times10^{-6}\ \text{C})}{(0.0250\ \text{m})^2}$$
$$= 35.10\ \text{N}$$

Use trigonometry to determine the angle θ_1 for the direction of $\vec{F}_{AC}$:



$$\tan\theta_1 = \frac{0.0435\ \text{m}}{0.0250\ \text{m}}$$
$$\theta_1 = 60.11°$$

Resolve $\vec{F}_{AC}$ into x and y components:



$$F_{AC_x} = (12.50\ \text{N})(\sin 60.11°)$$
$$= 10.84\ \text{N}$$
$$F_{AC_y} = -(12.50\ \text{N})(\cos 60.11°)$$
$$= -6.229\ \text{N}$$

The electrostatic force of charge B on charge C has only a y component:

$$F_{BC_x} = 0\ \text{N}$$
$$F_{BC_y} = 35.10\ \text{N}$$

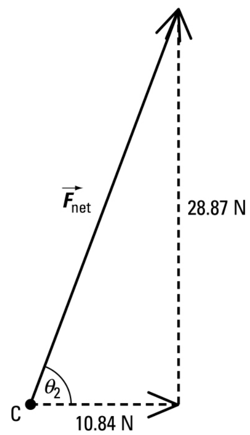
Add the x and y components:

$$F_{net_x} = 0\ \text{N} + 10.84\ \text{N}$$
$$= 10.84\ \text{N}$$
$$F_{net_y} = 35.10\ \text{N} + (-6.229\ \text{N})$$
$$= 28.87\ \text{N}$$

Then determine the magnitude of the force, using the Pythagorean theorem:

$$\left|\vec{F}_{net}\right| = \sqrt{(10.84\ \text{N})^2 + (28.87\ \text{N})^2}$$
$$= 30.8\ \text{N}$$

Use trigonometry to determine the direction of the net electrostatic force on charge C.



Determine the angle θ_2:

$$\tan\theta_2 = \frac{28.87\text{ N}}{10.84\text{ N}}$$
$$\theta_2 = 69.4°$$

The direction of the net force is 69.4°.

Paraphrase

(a) The net electrostatic force on sphere C midway between charges A and B is 113 N [right].

(b) The net electrostatic force on sphere C 2.50 cm right of charge B is 28.4 N [left].

(c) The net electrostatic force on sphere C 2.50 cm down from charge B is 30.8 N [69.4°].

60. ***Given***

$q = 1.6 \times 10^{-19}$ C
$m = 3.3 \times 10^{-27}$ kg
$v = 8.0 \times 10^{5}$ m/s

Required

potential difference required to accelerate the deuteron (V)

Analysis and Solution

The initial electric potential energy of the deuteron at the positive plate is:

$E_{p_i} = Vq$

Since it is at rest, its initial kinetic energy is:

$E_{k_i} = 0$ J

The final electric potential energy of the deuteron at the negative plate is:

$E_{p_f} = 0$ J

Since this system is conservative, a loss of electric potential energy is converted to a gain of kinetic energy, according to the law of conservation of energy:

$$E_{p_i} + E_{k_i} = E_{p_f} + E_{k_f}$$

$$Vq + 0\text{ J} = 0\text{ J} + \frac{1}{2}mv^2$$

$$V = \frac{\frac{1}{2}mv^2}{q}$$

$$= \frac{\frac{1}{2}\left(3.3 \times 10^{-27}\text{ kg}\right)\left(8.0 \times 10^{5}\text{ m/s}\right)^2}{1.6 \times 10^{-19}\text{ C}}$$

$$= 6.6 \times 10^{3}\text{ V}$$

Paraphrase

The potential difference required to accelerate the deuteron is 6.6×10^3 V.

61. ***Given***

$|\vec{E}| = 7.81 \times 10^{6}$ N/C

$\Delta d = 3.20$ mm $= 3.20 \times 10^{-3}$ m

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

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

$|\vec{B}| = 1.50$ T

Required

(a) voltage between the plates (V)

(b) maximum speed of the electron between the plates (v)

(c) magnetic force on the electron $\left(\vec{F}_{\text{m}}\right)$

(d) motion of the electron through the electric field and through the magnetic field

Analysis and Solution

(a) To calculate voltage between the plates, use the equation:

$$|\vec{E}| = \frac{\Delta V}{\Delta d}$$

$$\Delta V = |\vec{E}|\Delta d$$

$$= (7.81 \times 10^{6}\text{ N/C})(3.20 \times 10^{-3}\text{ m})$$

$$= 2.499 \times 10^{4}\text{ V}$$

(b) This system is conservative. You can use kinetic energy of the electron to find its speed.

The initial electric potential energy of the sphere at the positive plate is $E_{p_i} = Vq$. Since the sphere was at rest, its initial kinetic energy, E_{k_i}, is 0 J.

The final electric potential energy of the sphere at the negative plate is $E_{p_f} = 0$ J.

According to the law of conservation of energy,

$$E_{p_i} + E_{k_i} = E_{p_f} + E_{k_f}$$
$$Vq + 0\text{ J} = 0\text{ J} + E_{k_f}$$
$$\begin{aligned} E_{k_f} &= Vq \\ &= (2.499\times10^{4}\text{ V})(1.60\times10^{-19}\text{ C}) \\ &= 3.999\times10^{-15}\text{ J} \end{aligned}$$

Since $E_k = \frac{1}{2}mv^2$,

$$\begin{aligned} v &= \sqrt{\frac{2(3.999\times10^{-15}\text{ J})}{9.11\times10^{-31}\text{ kg}}} \\ &= 9.369\times10^{7}\text{ m/s} \end{aligned}$$

(c) Determine the magnitude of the magnetic deflecting force:

$$\begin{aligned} \left|\vec{F}_{\text{m}}\right| &= qv_{\perp}\left|\vec{B}\right| \\ &= (1.60\times10^{-19}\text{ C})(9.369\times10^{7}\text{ m/s})(1.50\text{ T}) \\ &= 2.249\times10^{-11}\text{ N} \end{aligned}$$

(d) As the electron travels through the electric field, parallel to the electric field lines, the electron accelerates in a parabolic path in a direction opposite to the direction of the electric field (i.e., toward the positive plate). As the electron enters the magnetic field, it deflects in a circular arc.

Paraphrase

(a) The voltage between the plates is 2.50×10^{4} V.

(b) The speed of the electron at the positive plate is 9.37×10^{7} m/s.

(c) The magnitude of the magnetic force on the electron is 2.25×10^{-11} N.

62. (a) As the north pole of the magnet approaches the coil, the wires in the coil cut the magnetic field lines of the magnet, which generates a voltage in the coils through electromagnetic induction. An induced current in the coil will then register a reading in the galvanometer.

(b) The induced current in the coil of wire, generated by the movement of the magnet through the coils, travels through the coil in a circular direction. This circular charge movement produces a secondary magnetic field, similar to the field produced by a bar magnet. The direction of this secondary magnetic field will be such as to oppose the initial motion of the magnet. If the north pole of the magnet is approaching the coil, current in the coil will be in a direction to produce a north pole at that end of the coil to oppose the motion of the approaching magnet, i.e., clockwise.

(c) As the magnet is pulled away from the coil, a similar voltage is produced, through electromagnetic induction, as the voltage produced in part (a). The direction of the induced current will be in the opposite direction, compared to the current in part (a), i.e., counterclockwise.

(d) The direction of the induced current in the coil will be such as to produce a magnetic field with a south pole at that end of the coil to oppose the motion of the north pole of the magnet away from the coil.

Extensions

63. The metal casing shields the sensitive inner electrical components from outside electrical interference.

64. The metal car body is similar to a hollow metal conductor, so charges accumulate on the outside surface of the car. The inside cannot have a charge, so the net electric field inside the car must be zero.

65. Black holes are caused by the tremendous gravitational forces attracting masses into an extremely dense centre. The forces cannot be electrical or magnetic because these forces cannot act on objects with no charge or no magnetic properties.

66. Electrical discharge from the workers could damage sensitive electronic equipment.

67. Charged particles from the Sun are trapped by Earth's magnetic field and move in a helical path along Earth's magnetic field lines toward the north pole due to the magnetic force. As the magnetic field lines of Earth's magnetic field reach the poles, they dip toward Earth's surface. The magnetic deflecting force on the charged particles now has a component that is opposite to the motion of the particles. This causes the charged particles to deflect and move in a helical path along the magnetic field lines toward Earth's south pole, where the process repeats. The particles are now trapped in a "magnetic bottle."

68. These belts trap high-energy charged particles from space. A spacecraft entering these regions would experience serious damage to sensitive electronic equipment.

69. **(a)** When a charged particle travels perpendicular to gravitational or electric fields, it accelerates in a parabolic path. When a charged particle travels perpendicular to a magnetic field, it accelerates in a circular path.

(b) When a charged particle travels parallel to and in the same direction as gravitational or electric fields, it accelerates along the gravitational or electric field lines. When a charged particle travels parallel to and in the same direction as a magnetic field, it experiences no force and travels in uniform motion.

70. Pointed objects have a more intense electric field than nearby rounded objects, and thus are more likely to attract lightning strikes.

71. Initially, the magnetic domains of the steel beam are arranged in a random pattern. Over an extended period of time, the influence of the magnetic field of Earth causes the domains of the steel beam to line up along the magnetic field lines of Earth's magnetic field. The steel beams will become permanent magnets through the process of magnetization by contact. This effect cannot happen with a wood beam because the motion of charges, in the atoms of wood, does not create strong enough magnetic fields to create magnetic domains.

72. The small distance between the feet of the bird, in contact with the same wire, and the insulation of the wire, do not allow a high enough potential difference to sustain a sufficient current to harm the bird. The potential difference between two adjacent wires, however, may produce a high enough potential difference to harm the bird.

73. Magnetic field lines run along Earth's surface from the south pole to the north pole. Only at the equator do the magnetic field lines run parallel to the surface of Earth. At the magnetic poles, the magnetic field lines point perpendicularly downward toward the surface of Earth. The angle of the magnetic field lines and the surface of Earth is called the "dip" angle.

A directional compass cannot be used near the poles because the magnetic field lines will point downward and cannot affect a directional compass, which is held in a position parallel to the surface of Earth.

The angle between magnetic north of the magnetic field of Earth and true geographic north is called the angle of declination. A directional compass will point to magnetic north, so angular corrections must be made to locate true geographic north.

74. No. An electron at rest does not produce the magnetic field necessary to be influenced by an external magnetic field to produce the motor effect force required to move the electron.

75. The changing magnetic field produced near a high-voltage power line will produce magnetic field lines that vibrate back and forth. If a loop of wire is held in this vibrating magnetic field, the wire of the loop will cut these magnetic field lines, thus producing a voltage in the loop that, in turn, induces a current in the loop. This current can be registered in the galvanometer.

76. The row of magnetite crystals can detect the magnetic field lines of Earth's magnetic field, enabling the bacterium to navigate, in proper directions. To test this hypothesis, place the bacterium near the stronger magnetic field of a bar magnet, and observe if the movement of the bacterium changes.

Skills Practice

77. Similarities listed in the overlapping parts of the Venn diagram:

Both are vector fields. Both vary with $\frac{1}{r^2}$.

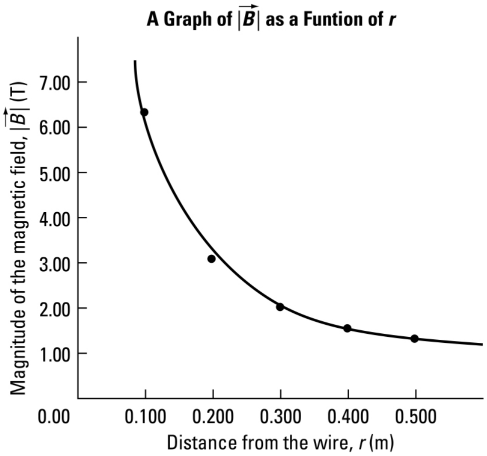
Both can exert attractive and repulsive forces.
Both are very strong forces.
Differences listed in the electric field circle of the Venn diagram:
An electric field originates from one charge and extends in straight lines to infinity or originates from infinity to the charge.
Differences listed in the magnetic field circle of the Venn diagram:
A magnetic field extends from one pole and curves to another.

78. Students' answers will vary but will likely take the following approaches:
for a gravitational field — an experiment to see which way a test mass will travel if placed in the field
for an electric field — an experiment to see which way a positive test charge will travel if placed in the field
for a magnetic field — an experiment to see which way the north pole of a small compass needle will point

79. Students' answers will vary but their concept maps should cover the following steps:
Determine the electrostatic force of the other two charges on one charge.
Determine the angles of each electrostatic force on the charge.
Determine the x and y components of each force.
Determine the sum of the x components and the sum of the y components.
Draw vector diagrams of these sums.
Determine the resultant force and the angle using trigonometry.

80. Students' answers will vary but the experiment could be similar to Part B of 10-3 Inquiry Lab on page 526.

81. (a)



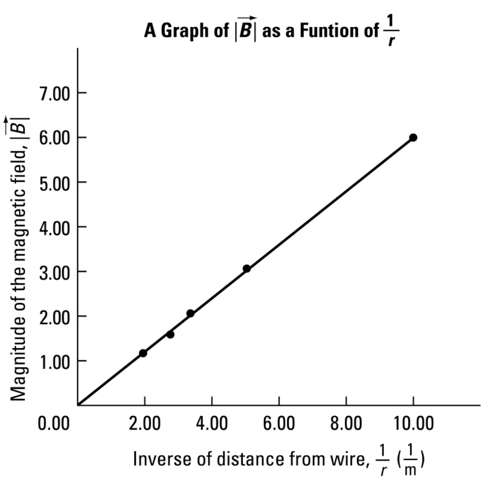
(b) $\left|\vec{B}\right| \propto \frac{1}{r}$

(c) To straighten the graph, plot $\left|\vec{B}\right|$ as a function of $\frac{1}{r}$.

(d)

Inverse of the distance from the wire $\frac{1}{r}\left(\frac{1}{\text{m}}\right)$	Magnetic field ($\left\|\vec{B}\right\|$ (T))
10.0	6.28
5.00	3.14
3.33	2.09
2.50	1.57
2.00	1.26

(e)



(f) slope $= \dfrac{\text{rise}}{\text{run}}$

$$= \frac{6.3\ \text{T}}{10.00\ \frac{1}{\text{m}}}$$

$$= 0.63\ \text{T}\cdot\text{m}$$

Since slope $= \dfrac{\text{rise}}{\text{run}}$,

$$= \frac{|\vec{B}|}{\frac{1}{r}}$$

$$= |\vec{B}|r$$

$$|\vec{B}|r = \frac{\mu I}{2\pi}$$

$$\mu = \frac{|\vec{B}|r2\pi}{I}$$

$$= \frac{(0.63\ \text{T}\cdot\text{m})2\pi}{5.00\ \text{A}}$$

$$= 0.79\ \text{T}\cdot\text{m/A}$$

(g) $\mu = \dfrac{|\vec{B}|r2\pi}{I}$

$$= \frac{(6.28\ \text{T})(0.100\ \text{m})2\pi}{5.00\ \text{A}}$$

$$= 0.789\ \text{T}\cdot\text{m/A}$$

Self-assessment

Students' answers in this section will vary greatly depending on their experiences, depth of understanding, and the depth of the research that they do into each of the topics.

