

Chapter Summary***Electricity-Electric Fields***

Test Charge (q_0) – An object with a very small magnitude of charge so as to not disturb the system. It is used to determine the extent to which surrounding charges generate a force.

Electric Fields

The electric field (E) is the force per Coulomb, F/q_0 , experienced by a test charge in the presence of other charged object(s). Through this definition it should be clear that the electric field is a vector quantity that points in the same direction as the electric force for positive point charges. The force and field point opposite for a negative point charge. It is the surrounding charges that create an electric field at a given point. All surrounding charges contribute to the net electric field. To determine the net electric field it is necessary to determine all of the individual electric fields and then find the vector sum.

Point Charges

Point charges are used to determine the electric field around electrically charged objects because the equations simplify. If Coulomb's law is considered using q_0 for the point charge and q for the charge in question the equation becomes

$$F = \frac{kqq_0}{r^2}$$

In the above equation divide both sides by q_0 to get

$$\frac{F}{q_0} = \frac{kq}{r^2} \text{ then } E = \frac{kq}{r^2}$$

This shows how the charge of the point charge is not needed to determine the field experienced by a charge. Often symmetry in problems will prove to simplify the solution and provide useful information.

Electric Field Lines

Since electric charges create electric fields in the space surrounding them it is useful to have a map that gives the directions and magnitudes of all of the electric fields present at different locations. Michael Faraday set up an experiment that determined electric field lines point radially outward from a positive charge. The electric field lines were found to point radially inward toward negative charges. This makes sense in the opposites attract and opposites repel. The field lines are found 360 degrees around the charge, however only some are drawn to eliminate confusion. The amount of field lines indicates the strength, so a point with 5 times the number of lines than a point with charge $+q$ would indicate a charge of $+5q$. The pattern of electric field lines also indicates the magnitude or the strength of the field. When field lines are close together that would indicate a stronger field strength. When the field lines are further spaced apart, further from the center of charge, the field strength is weaker.

Electric Dipoles

Often electric field lines are curved, as in the case of electric dipoles. A dipole consists of two electric charges of equal magnitude but opposite sign. The electric field of a dipole is proportional to the product of the magnitude of one of the charges and the distance between the charges (called the dipole moment). The pattern of the lines for the dipole indicates that the electric field is greatest in the region between and immediately surrounding the two charges, since the lines are closest together there. For any given field line, it originates at the positive charge and ends on the negative charge. In general, electric field lines always begin on a positive charge and end on a negative charge and do not start or stop in midspace. Furthermore, the number of field lines leaving a positive charge or entering a

negative charge is proportional to the magnitude of the charge. So if 100 field lines were drawn out of a +4q charge, then 75 would be drawn for a +3q charge and 25 for +q. For two identical charges the electric field lines are curved. For two positive charges, there is an absence of field lines between the charges, this indicates a weak field directly between the charges. When drawing electric field lines be sure that they never cross over one another, they can never be crossed.

The Parallel Plate Capacitor

The equation for the electric field of a point charge can be reevaluated using calculus to be derived for point charges distributed over a surface. One example of this is the charge and electric field on a parallel plate capacitor. Each plate has an area, A, with one plate having a charge of +q and the other a charge of -q. The charges are spread uniformly across the area of the plate. In the region between the plates and away from the edges, the electric field points from the positive plate toward the negative plate and perpendicular to both. Gauss' law can be used to show the magnitude of the electric field, it says

$$E = \frac{q}{\epsilon_0 A} = \frac{\sigma}{\epsilon_0}$$

Sigma (σ) denotes the charge per unit area (q/A) of the plate, also called the charge density. The field has the same value at all places between the plates, except by the edges. Note the field does not depend on the distance of the charges from the plates, whereas the isolated point charge does depend on distance.

Potential Energy

Electric potential energy is analogous to gravitational potential energy. If a point charge, + q_0 , were placed between two oppositely charged plates. The force experienced by the point charge, $F=q_0E$, would be directed toward the negative plate. Therefore the

work done by the electric force equals the difference between the electric potential at A and that at B:

$$W_{AB} = EPE_A - EPE_B$$

The Electric Potential Difference

Since the work done depends on the charge q_0 , the work is usually expressed per unit charge. The equation becomes:

$$\frac{W_{AB}}{q_0} = \frac{EPE_A}{q_0} - \frac{EPE_B}{q_0}$$

Electric potential is the electric potential energy of a small test charge divided by the charge itself. The equation for the electric potential, V, is defined as

$$V = \frac{EPE}{q_0}$$

Where the electric potential (V) is in units of Joules (EPE) per Coulomb (q_0), or J/C which is called the volt.

The electric potential can be related to the work equation

$$\Delta V = V_B - V_A = \frac{EPE_B}{q_0} - \frac{EPE_A}{q_0} = \frac{-W_{AB}}{q_0}$$

Neither the electric potential nor the potential difference can be determined for one value, but rather only the differences can be determined.

As a positive point charge, q_0 , accelerates from an area of higher electric potential to an area of lower electric potential in the direction of the oppositely charged plate. If a point charge of $-q_0$ were to be in the same electric field it would accelerate in the opposite direction, toward the other plate. Therefore a negative charge accelerates from an area of lower electric potential energy to an area of higher electric potential.

EXAMPLE 7 • An Electric Field Leads to a Force

In Figure 18.18a the charges on the two metal spheres and the ebonite rod create an electric field \mathbf{E} at the spot indicated. This field has a magnitude of 2.0 N/C and is directed as in the drawing. Determine the force on a charge placed at that spot, if the charge has a value of (a) $q_0 = +18 \times 10^{-8}$ C and (b) $q_0 = -24 \times 10^{-8}$ C.

Reasoning The electric field at a given spot can exert a variety of forces, depending on the magnitude and sign of the charge placed there. The charge is assumed to be small enough that it does not alter the locations of the surrounding charges that create the field.

Solution

(a) The magnitude of the force is the product of the magnitudes of q_0 and \mathbf{E} :

$$F = q_0 E = (18 \times 10^{-8} \text{ C})(2.0 \text{ N/C}) = \boxed{36 \times 10^{-8} \text{ N}} \quad (18.2)$$

Since q_0 is positive, the force points in the same direction as the electric field, as part b of the drawing indicates.

(b) In this case, the magnitude of the force is

$$F = q_0 E = (24 \times 10^{-8} \text{ C})(2.0 \text{ N/C}) = \boxed{48 \times 10^{-8} \text{ N}} \quad (18.2)$$

The force on the negative charge points in the direction *opposite* to the force on the positive charge, that is, opposite to the electric field (see part c of the drawing).

EXAMPLE 8 • Electric Fields Add as Vectors Do

Figure 18.19 shows two charged objects, A and B. Each contributes as follows to the net electric field at point P: $\mathbf{E}_A = 3.00$ N/C directed to the right, and $\mathbf{E}_B = 2.00$ N/C directed downward. Thus, \mathbf{E}_A and \mathbf{E}_B are perpendicular. What is the net electric field at P?

Reasoning The net electric field \mathbf{E} is the vector sum of \mathbf{E}_A and \mathbf{E}_B : $\mathbf{E} = \mathbf{E}_A + \mathbf{E}_B$. As illustrated in Figure 18.19, \mathbf{E}_A and \mathbf{E}_B are perpendicular, so \mathbf{E} is the diagonal of the rectangle formed by \mathbf{E}_A and \mathbf{E}_B . Thus, we can use the Pythagorean theorem to find the magnitude of \mathbf{E} and trigonometry to find the directional angle θ .

Solution The magnitude of the net electric field is

$$E = \sqrt{E_A^2 + E_B^2} = \sqrt{(3.00 \text{ N/C})^2 + (2.00 \text{ N/C})^2} = \boxed{3.61 \text{ N/C}}$$

The direction of \mathbf{E} is given by the angle θ in the drawing:

$$\theta = \tan^{-1} \left(\frac{E_B}{E_A} \right) = \tan^{-1} \left(\frac{2.00 \text{ N/C}}{3.00 \text{ N/C}} \right) = \boxed{33.7^\circ}$$

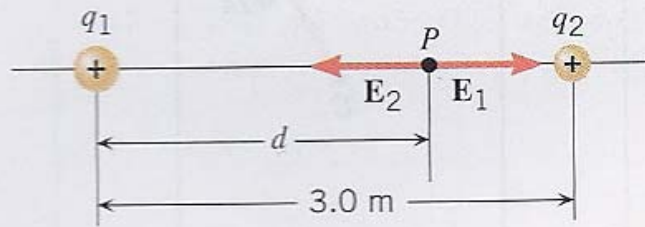


Figure 18.21 The two point charges q_1 and q_2 create electric fields \mathbf{E}_1 and \mathbf{E}_2 that cancel at a location P on the line between the charges.

EXAMPLE 10 • The Electric Fields From Separate Charges May Cancel

Two positive point charges, $q_1 = +16 \mu\text{C}$ and $q_2 = +4.0 \mu\text{C}$, are separated in a vacuum by a distance of 3.0 m, as Figure 18.21 illustrates. Find the spot on the line between the charges where the net electric field is zero.

Reasoning Between the charges the two field contributions have opposite directions, and the net electric field is zero at the place where the magnitude of \mathbf{E}_1 equals that of \mathbf{E}_2 . However, since q_2 is smaller than q_1 , this location must be *closer* to q_2 , in order that the field of the smaller charge can balance the field of the larger charge. In the drawing, the cancellation spot is labeled P , and its distance from q_1 is d .

Solution At P , $E_1 = E_2$, and using the expression $E = kq/r^2$, we have

$$\frac{k(16 \times 10^{-6} \text{ C})}{d^2} = \frac{k(4.0 \times 10^{-6} \text{ C})}{(3.0 \text{ m} - d)^2}$$

Rearranging this expression shows that $4.0(3.0 \text{ m} - d)^2 = d^2$. Taking the square root of each side of this equation reveals that

$$2.0(3.0 \text{ m} - d) = \pm d$$

The plus and minus signs on the right occur because either the positive or negative root can be taken. Therefore, there are two possible values for d : +2.0 m and +6.0 m. The value +6.0 m corresponds to a location off to the right of both charges, where the magnitudes of \mathbf{E}_1 and \mathbf{E}_2 are equal, but where the directions are the same. Thus, \mathbf{E}_1 and \mathbf{E}_2 do not cancel at this spot. The other value for d corresponds to the location shown in the drawing and is the zero-field location: $d = +2.0 \text{ m}$.

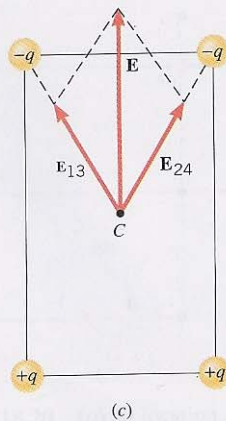
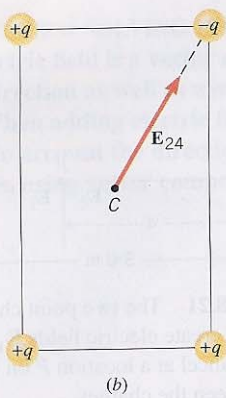
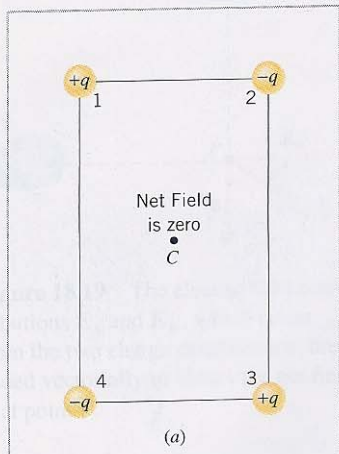


Figure 18.22 Charges of identical magnitude, but different signs, are placed at the corners of a rectangle. The charges give rise to different electric fields at the center C of the rectangle, depending on the signs of the charges.

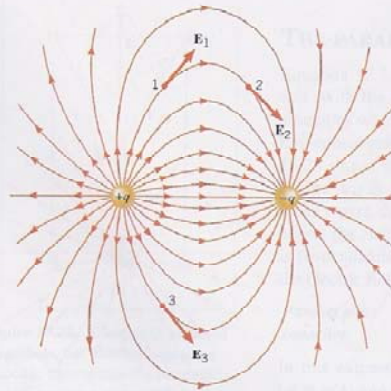


Figure 18.27 The electric field lines of an electric dipole are curved and extend from the positive to the negative charge. At any point, such as 1, 2, or 3, the field created by the dipole is tangent to the line through the point.

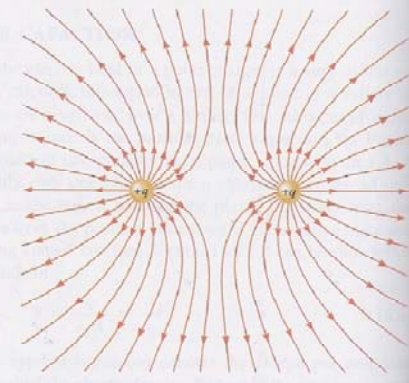


Figure 18.28 The electric field lines for two identical positive point charges. If the charges were both negative, the directions of the lines would be reversed.

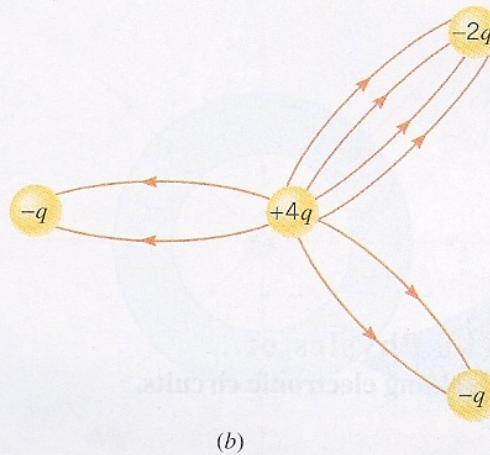
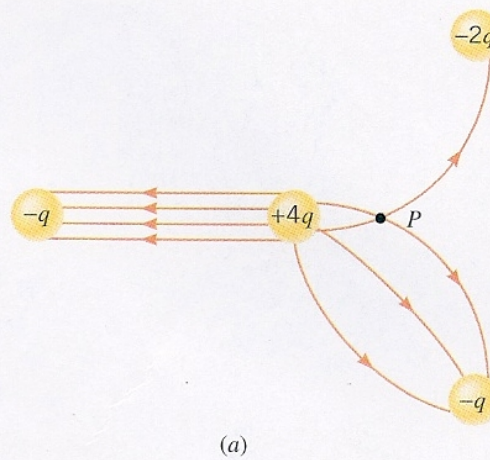
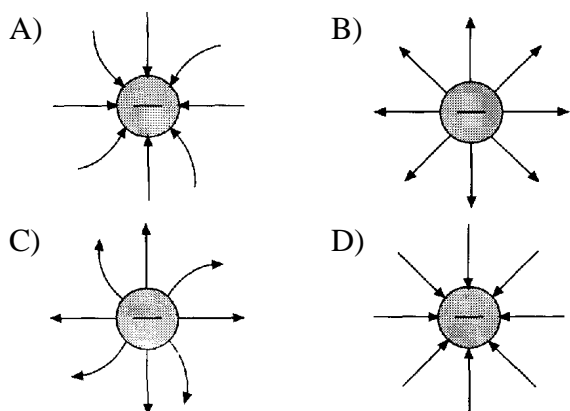


Figure 18.29 (a) Incorrectly and (b) correctly drawn electric field lines.

1. Which diagram best represents the electric field around a negatively charged conducting sphere?



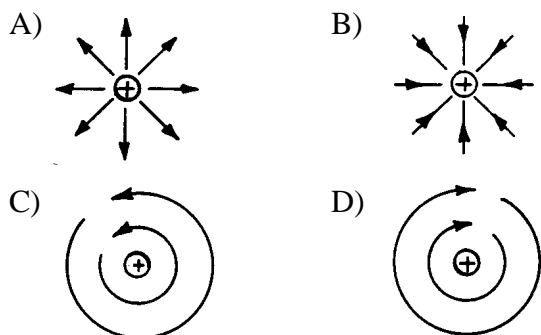
2. In the diagram below, A is a point near a positively charged sphere.



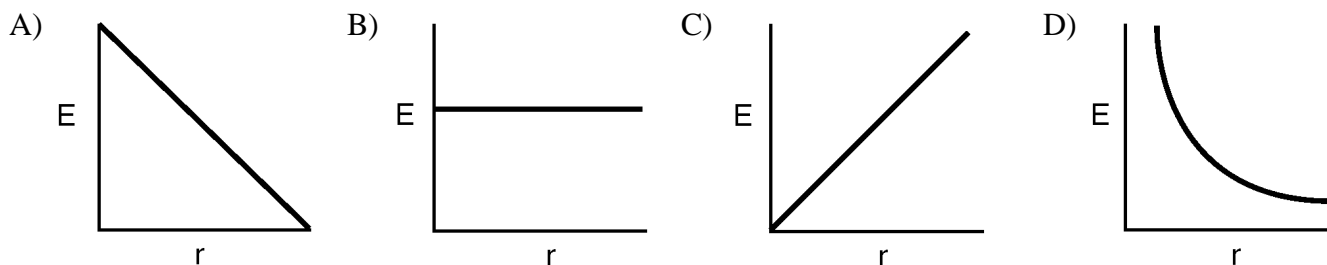
Which vector best represents the direction of the electric field at point A?



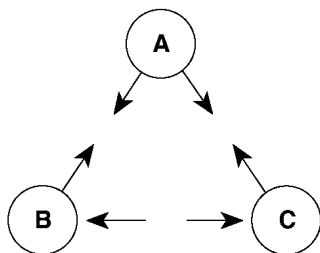
3. Which diagram best represents the electric field surrounding a positive point charge?



4. Which graph best represents the relationship between the magnitude of the electric field strength, E , around a point charge and the distance, r , from the point charge?



5. The diagram below shows the arrangement of three charged hollow metal spheres, A , B , and C . The arrows indicate the direction of the electric forces acting between the spheres. At least two of the spheres are positively charged.

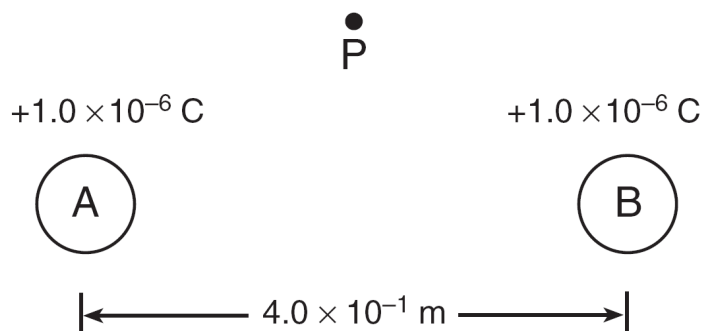


Which sphere, if any, could be negatively charged?

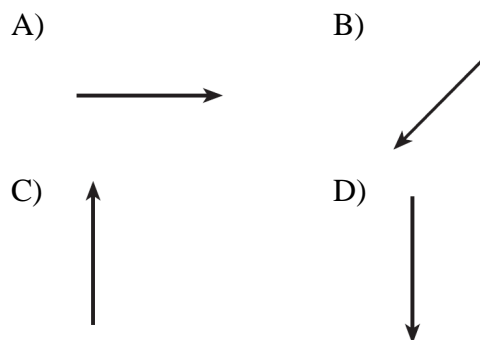
- A) sphere A
- B) sphere B
- C) sphere C
- D) no sphere

Base your answer to the following question on the information and diagram below.

Two small metallic spheres, A and B , are separated by a distance of 4.0×10^{-1} meter, as shown. The charge on each sphere is $+1.0 \times 10^{-6}$ coulomb. Point P is located near the spheres.



6. Which arrow best represents the direction of the resultant electric field at point P due to the charges on spheres A and B ?



7. In the diagram below, P is a point near a negatively charged sphere.



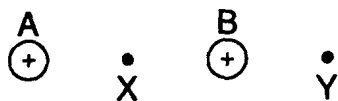
Which vector best represents the direction of the electric field at point P ?

- A) B)
- C) D)

8. Two positively charged masses are separated by a distance, r . Which statement best describes the gravitational and electrostatic forces between the two masses?

- A) Both forces are attractive.
 B) Both forces are repulsive.
 C) The gravitational force is repulsive and the electrostatic force is attractive.
 D) The gravitational force is attractive and the electrostatic force is repulsive.

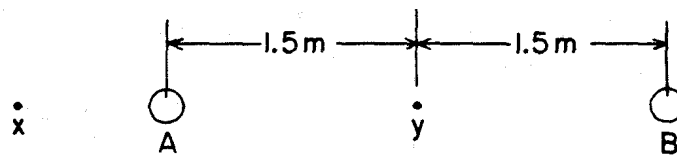
9. Two equal positive point charges, A and B are positioned as shown below.



At which location is the electric field intensity due to these two charges equal to zero?

- A) A B) B C) X D) Y

Base your answer to questions **10** and **11** on the diagram below which represents two small charged spheres, A and B , 3 meters apart. Each sphere has a charge of $+2.0 \times 10^{-6}C$.



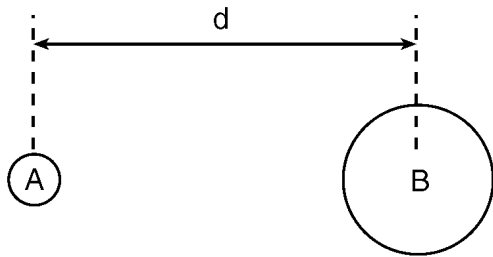
10. If a positive charge is placed at point x , the direction of the net force on the charge will be

- A) into the page B) out of the page
 C) toward the left D) toward the right

11. Which diagram best illustrates the electric field between charges A and B ?

- A) B) C) D)

12. In the diagram below, two positively charged spheres, *A* and *B*, of masses m_A and m_B are located a distance d apart.



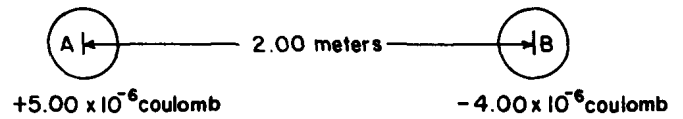
Which diagram best represents the directions of the gravitational force, F_g , and the electrostatic force, F_e , acting on sphere *A* due to the mass and charge of sphere *B*? [Vectors are not drawn to scale.]

- A) B)
- C)
- D)

13. Two protons are located one meter apart. Compared to the gravitational force of attraction between the two protons, the electrostatic force between the protons is

- A) stronger and repulsive
 B) weaker and repulsive
 C) stronger and attractive
 D) weaker and attractive

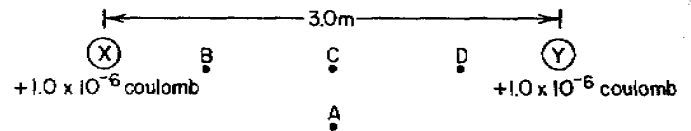
Base your answer to the following question on the diagram below which represents two small, charged conducting spheres, identical in size, located 2.00 meters apart.



14. Which diagram best represents the electric field between the two spheres?

- A) B)
- C) D)

Base your answer to questions 15 and 16 on the diagram below which represents two charged spheres, *X* and *Y*.



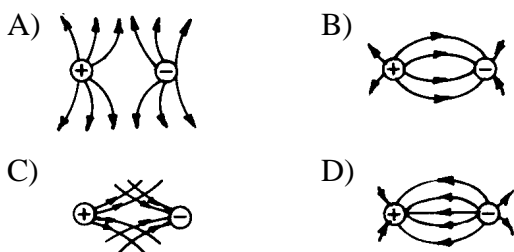
15. Moving the two spheres toward each other would cause their electrical potential energy to

- A) decrease B) increase
 C) remain the same

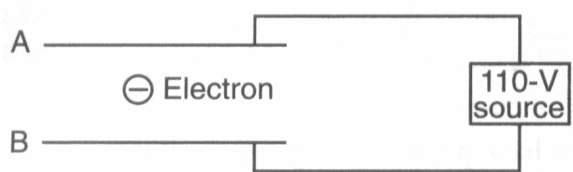
16. Which arrow best represents the direction of the electric field at point *A*?

- A) B) C) D)

17. Which diagram best illustrates the electric field around two unlike charges?



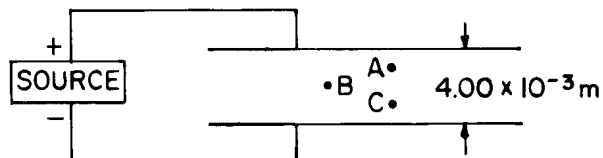
18. An electron is located in the electric field between two parallel metal plates as shown in the diagram below.



If the electron is attracted to plate A, then plate A is charged

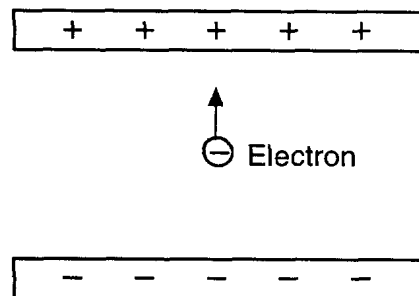
- A) positively, and the electric field is directed from plate A toward plate B
- B) positively, and the electric field is directed from plate B toward plate A
- C) negatively, and the electric field is directed from plate A toward plate B
- D) negatively, and the electric field is directed from plate B toward plate A

Base your answer to questions 19 through 21 on the diagram below which represents a voltage source connected to two large, parallel metal plates. The electric field intensity between the plates is 3.75×10^4 Newtons per coulomb.



- 19. If the source is replaced with one having twice the potential difference and the distance between the plates is halved, the electric field intensity between the plates will
 - A) decrease
 - B) increase
 - C) remain the same
- 20. What is the potential difference of the source?
 - A) 9.38×10^5 V
 - B) 4.00×10^3 V
 - C) 3.75×10^2 V
 - D) 1.50×10^2 V
- 21. As a proton moves from A to B to C, the electric force on the proton
 - A) decreases
 - B) increases
 - C) remains the same

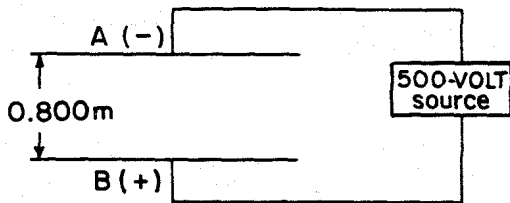
22. An electron is placed between two oppositely charged parallel plates as shown in the diagram below.



As the electron moves toward the positive plate, the magnitude of the electric force acting on the electron

- A) decreases
- B) increases
- C) remains the same

Base your answer to questions 23 and 24 on the diagram below which shows two parallel metal plates A and B connected to a voltage source.



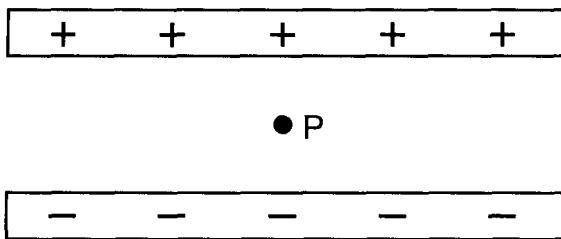
23. If an object carrying a charge of 2 elementary charges starts from rest at plate A and is accelerated to plate B by the electric field, the total work done by the electric field on the object is

- A) 200. eV
- B) 250. eV
- C) 500. eV
- D) 1,000 eV

24. As a charged object moves from plate A to plate B, the electric force on the charged object

- A) decreases
- B) increases
- C) remains the same

25. The diagram below shows a point, P, located midway between two oppositely charged parallel plates.

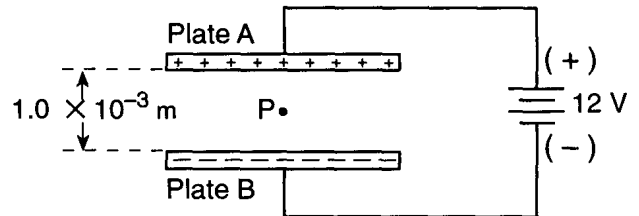


If an electron is introduced at point P, the electron will

- A) travel at constant speed toward the positively charged plate
- B) travel at constant speed toward the negatively charged plate
- C) accelerate toward the positively charged plate
- D) accelerate toward the negatively charged plate

Base your answer to the following question on the information and diagram below.

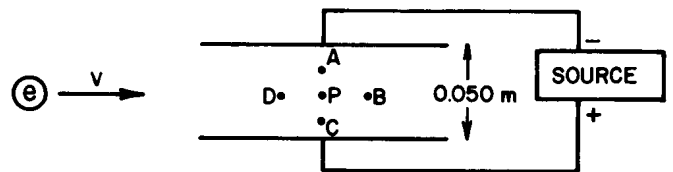
Two parallel plates separated by a distance of 1.0×10^{-3} meter are charged to a potential difference of 12 volts. An alpha particle with a charge of +2 elementary charges is located at point P in the region between the plates



26. The electric field between the plates will cause the alpha particle, starting from rest at point P, to

- A) accelerate toward the positive plate
- B) accelerate toward the negative plate
- C) move at constant speed toward the positive plate
- D) move at constant speed toward the negative plate

Base your answer to questions 27 and 28 on the diagram below which represents two large parallel conducting plates charged to a potential of 10. volts. The plates are separated by a distance of 0.050 meter.



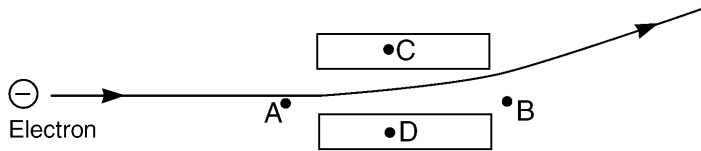
27. If an electron were projected into the electric field with a velocity v , it would experience a deflection

- A) into the page
- B) out of the page
- C) toward the top of the page
- D) toward the bottom of the page

28. The direction of the electric field at point P is toward point

- A) A
- B) B
- C) C
- D) D

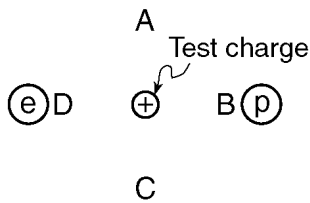
29. A moving electron is deflected by two oppositely charged parallel plates, as shown in the diagram below.



The electric field between the plates is directed from

- A) *A* to *B* B) *B* to *A* C) *C* to *D* D) *D* to *C*

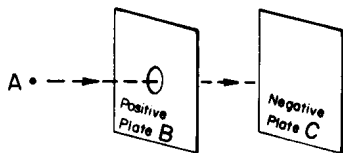
30. A positive test charge is placed between an electron, *e*, and a proton, *p*, as shown in the diagram below.



When the test charge is released, it will move toward

- A) *A* B) *B* C) *C* D) *D*

31. A beam of electrons is fired from point *A* toward plate *B* as shown in the diagram.



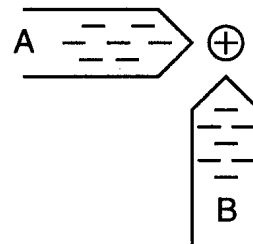
After the beam passes through a hole in positively charged plate *B*, the electrons will

- A) speed up
 B) slow down
 C) be pushed up
 D) be pushed toward the right





32. A proton and an electron traveling with the same velocity enter a uniform electric field. Compared to the acceleration of the proton, the acceleration of the electron is

- A) less, and in the same direction
 B) less, but in the opposite direction
 C) greater, and in the same direction
 D) greater, but in the opposite direction

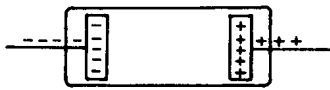
33. Two plastic rods, *A* and *B*, each possess a net negative charge of 1.0×10^{-3} coulomb. The rods and a positively charged sphere are positioned as shown below.



Which vector best represents the resultant electrostatic force on the sphere?

- A)  B) 
 C)  D) 

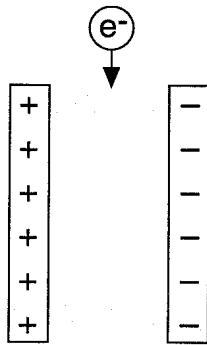
34. The diagram below represents oppositely charged plates in an evacuated glass tube.



Which diagram below represents the path of free electrons between the charged plates?

- A) B)
 C)
 D)

Base your answer to the following question on the diagram below which represents an electron being projected between two oppositely charged parallel plates.



35. In which direction will the electric field deflect the electron?
 A) into the page B) out of the page
 C) to the right D) to the left
36. An electron is located between a pair of oppositely charged parallel plates. As the electron approaches the positive plate, the kinetic energy of the electron
 A) decreases B) increases
 C) remains the same

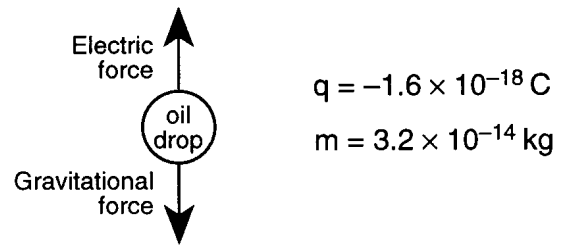
37. Gravitational field strength is to Newtons per kilogram as electric field strength is to

- A) coulombs per joule
 B) coulombs per newton
 C) joules per coulomb
 D) newtons per coulomb

38. What force will a proton experience in a uniform electric field whose strength is 2.00×10^5 Newtons per coulomb?

- A) 8.35×10^{24} N B) 1.67×10^5 N
 C) 3.20×10^{-14} N D) 1.67×10^{-14} N

39. The diagram below, which illustrates the Millikan oil drop experiment, shows a 3.2×10^{-14} -kilogram oil drop with a charge of -1.6×10^{-18} coulomb. The oil drop was in equilibrium when the upward electric force on the drop was equal in magnitude to the gravitational force on the drop.



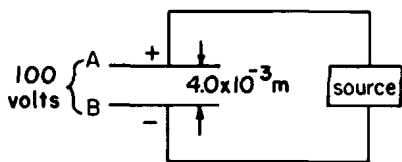
What was the magnitude of the electric field intensity when this oil drop was in equilibrium?

- A) 2.0×10^{-5} N/C B) 2.0×10^5 N/C
 C) 5.0×10^{-5} N/C D) 5.0×10^5 N/C
40. A charged particle is placed in an electric field E . If the charge on the particle is doubled, the force exerted on the particle by the field E is
 A) unchanged B) doubled
 C) halved D) quadrupled

41. What is the magnitude of the electric field intensity at a point in the field where an electron experiences a 1.0-newton force?

A) 10 N/C B) 1.6×10^{-19} N/C
 C) 6.3×10^{18} N/C D) 9.1×10^{-31} N/C

Base your answer to the following question on the diagram below which shows two large parallel metal plates connected to a source of electric potential. The plates are 4.0×10^{-3} meter apart and the potential difference across the plates is 100 volts.



42. As an electron moves from plate *B* toward plate *A*, the electric force on the electron

A) decreases B) increases
 C) remains the same

43. What is the charge on an object that experiences a force of 5 Newtons in an electric field of 50 Newtons per coulomb?

A) 10 C B) 2.0 C C) 0.2 C D) 0.1 C

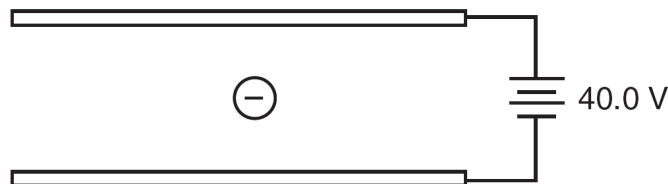
44. A distance of 1.0×10^3 meters separates the charge at the bottom of a cloud and the ground. The electric field intensity between the bottom of the cloud and the ground is 2.0×10^4 Newtons per coulomb. What is the potential difference between the bottom of the cloud and the ground?

A) 1.3×10^{23} V B) 2.0×10^1 V
 C) 2.0×10^7 V D) 5.0×10^{-2} V

45. What is the magnitude of the electric field intensity at a point where a proton experiences an electrostatic force of magnitude 2.30×10^{-25} newton?

A) 3.68×10^{-44} N/C B) 1.44×10^{-6} N/C
 C) 3.68×10^6 N/C D) 1.44×10^{44} N/C

46. The diagram below represents an electron within an electric field between two parallel plates that are charged with a potential difference of 40.0 volts.



If the magnitude of the electric force on the electron is 2.00×10^{-15} newton, the magnitude of the electric field strength between the charged plates is

A) 3.20×10^{-34} N/C B) 2.00×10^{-14} N/C
 C) 1.25×10^4 N/C D) 2.00×10^{16} N/C

47. If 20 joules of work is used to transfer 20 coulombs of charge through a 20-ohm resistor, the potential difference across the resistor is

A) 1 V B) 20 V
 C) 0.05 V D) 400 V

48. The work required to move a charge of 3.0 coulombs through a potential difference of equal to 12 volts is

A) 0.25 joule B) 9 joules
 C) 36 joules D) 4.0 joules

49. If 15 joules of work is required to move 3.0 coulombs of charge between two points, the potential difference between these two points is

A) 45 V B) 15 V C) 3.0 V D) 5.0 V

50. Moving a point charge of 3.2×10^{-19} coulomb between points *A* and *B* in an electric field requires 4.8×10^{-19} joule of energy. What is the potential difference between these two points?

A) 0.67 V B) 2.0 V
 C) 3.0 V D) 1.5 V

51. Moving 2.5×10^{-6} coulombs of charge from point A to point B in an electric field requires 6.3×10^{-4} joules of work. The potential difference between points A and B is approximately

- A) 1.6×10^{-9} V B) 4.0×10^{-3} V
C) 2.5×10^2 V D) 1.0×10^{14} V

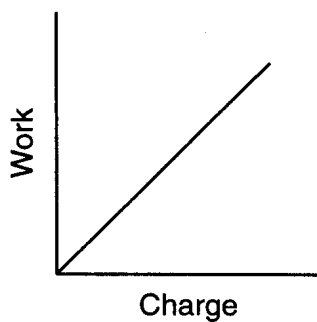
52. If 6.0 joules of work is done to move 2.0 coulombs of charge from point A to point B . what is the electric potential difference between points A and B ?

- A) 6.0 V B) 0.33 V
C) 3.0 V D) 12 V

53. How much work is required to move a single electron through a potential difference of 100. volts?

- A) 1.6×10^{-21} J B) 1.6×10^{-19} J
C) 1.6×10^{-17} J D) 1.0×10^2 J

54. The graph below shows the relationship between the work done on a charged body in an electric field and the net charge on the body.



What does the slope of this graph represent?

- A) power
B) potential difference
C) force
D) electric field intensity

55. If 1.0 joule of work is required to move a charge of 1.0 coulomb between two points in an electric field, the potential difference between these two points is

- A) 1.0 V B) 1.6×10^{-19} V
C) 9.0×10^9 V D) 6.3×10^{18} V

56. If 1.0 joule of work is required to move 1.0 coulomb of charge between two points in an electric field, the potential difference between the two points is

- A) 1.0×10^0 V B) 9.0×10^9 V
C) 6.3×10^{18} V D) 1.6×10^{-19} V

57. If 20.0 joules of work is needed to move 5.0 coulombs of electrical charge through a circuit, the voltage is

- A) 100 volts B) 25 volts
C) 0.25 volt D) 4.0 volts

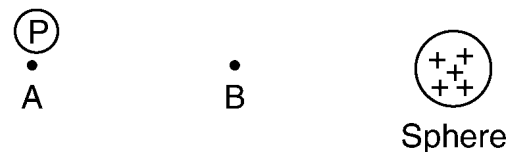
58. Moving 2.0 coulombs of charge a distance of 6.0 meters from point A to point B within an electric field requires a 5.0-newton force. What is the electric potential difference between points A and B ?

- A) 60. V B) 30. V C) 15 V D) 2.5 V

59. In an electric field, 0.90 joule of work is required to bring 0.45 coulomb of charge from point A to point B . What is the electric potential difference between points A and B ?

- A) 5.0 V B) 2.0 V
C) 0.50 V D) 0.41 V

60. The diagram below shows proton P located at point A near a positively charged sphere.



If 6.4×10^{-19} joule of work is required to move the proton from point A to point B , the potential difference between A and B is

- A) 6.4×10^{-19} V B) 4.0×10^{-19} V
C) 6.4 V D) 4.0 V