chapter 19 ELECTRIC POTENTIAL ENERGY AND THE ELECTRIC POTENTIAL

Section 19.1 Potential Energy
Section 19.2 The Electric Potential Difference

☐ 1. Which one of the following statements is true concerning the work done by an external force in moving an electron at constant speed between two points in an electrostatic field?
(a) The work done is always zero joules.
(b) The work done is always positive.
(c) The work done is always negative.
(d) The work done depends on the total distance covered.
(e) The work done depends only on the displacement of the electron.

☐ 2. Complete the following statement: The *electron volt* is a unit of
(a) energy.
(b) electric field strength.
(c) electric charge.
(d) electric potential difference.
(e) electric power.

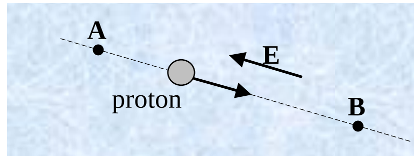
◘ 3. Which one of the following statements best explains why it is possible to define an *electrostatic potential* in a region of space that contains an *electrostatic field*?
(a) Work must be done to bring two positive charges closer together.
(b) Like charges repel one another and unlike charges attract one another.
(c) A positive charge will gain kinetic energy as it approaches a negative charge.
(d) The work required to bring two charges together is independent of the path taken.
(e) A negative charge will gain kinetic energy as it moves away from another negative charge.

◘ 4. The electric potential at a certain point is space is 12 V. What is the electric potential energy of a –3.0 μC charge placed at that point?
(a) +4 μJ
(b) –4 μJ
(c) +36 μJ
(d) –36 μJ
(e) zero μJ

☐ 5. A completely ionized beryllium atom (net charge = +4*e*) is accelerated through a potential difference of 6.0 V. What is the increase in kinetic energy of the atom?
(a) zero eV
(b) 0.67 eV
(c) 4.0 eV
(d) 6.0 eV
(e) 24 eV

◘ 6. Two positive point charges are separated by a distance *R*. If the distance between the charges is reduced to *R*/2, what happens to the total electric potential energy of the system?
(a) It is doubled.
(b) It remains the same.
(c) It increases by a factor of 4.
(d) It is reduced to one-half of its original value.
(e) It is reduced to one-fourth of its original value.

8. A proton moves in a constant electric field E from point A to point B. The magnitude of the electric field is 4.2×10^4 N/C; and it is directed as shown in the drawing, the direction opposite to the motion of the proton. If the distance from point A to point B is 0.18 m, what is the change in the proton's electric potential energy, EPEA – EPEB?

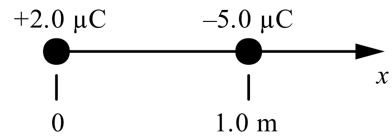


(a) $+2.4 \times 10^{-15}$ J
(b) -1.2×10^{-15} J
(c) $+1.2 \times 10^{-15}$ J
(d) -2.4×10^{-15} J
(e) -1.8×10^{-15} J

Section 19.3 The Electric Potential Difference Created by Point Charges

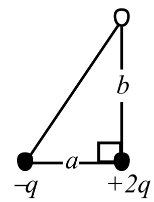
9. Two point charges are arranged along the *x* axis as shown in the figure. At which of the following values of *x* is the electric potential equal to zero?

Note: At infinity, the electric potential is zero.



(a) +0.05 m
(b) +0.29 m
(c) +0.40 m
(d) +0.54 m
(e) +0.71 m

10. Two point charges are located at two of the vertices of a right triangle, as shown in the figure. If a third charge $-2q$ is brought from infinity and placed at the third vertex, what will its electric potential energy be? Use the following values: a = 0.15 m; b = 0.45 m, and $q = 2.0 \times 10^{-5}$ C.



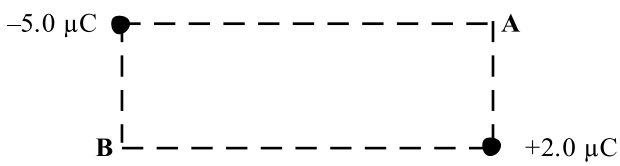
(a) –17 J
(b) –12 J
(c) –2.8 J
(d) +8.5 J
(e) +14 J

13. If the work required to move a +0.35 C charge from point **A** to point **B** is +125 J, what is the potential difference between the two points?

(a) zero volts
(b) 44 V
(c) 88 V
(d) 180 V
(e) 360 V

Questions 14 through 16 pertain to the electrostatic system described below:

Two point charges are held at the corners of a rectangle as shown in the figure. The lengths of sides of the rectangle are 0.050 m and 0.150 m. Assume that the electric potential is defined to be zero at infinity.



14. Determine the electric potential at corner **A**.

(a) $+6.0 \times 10^4$ V
(b) -2.4×10^5 V
(c) $+4.6 \times 10^5$ V
(d) -7.8×10^5 V
(e) zero volts

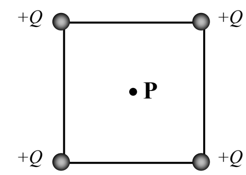
15. What is the potential difference, $V_B - V_A$, between corners **A** and **B**?

(a) -8.4×10^5 V
(b) -7.8×10^5 V
(c) -7.2×10^5 V
(d) -6.0×10^5 V
(e) zero volts

16. What is the electric potential energy of a +3.0 μC charge placed at corner **A**?

(a) 0.10 J
(b) 0.18 J
(c) 2.3 J
(d) 3.6 J
(e) zero joules

Questions 17 through 19 pertain to the situation described below:



Four point charges are individually brought from infinity and placed at the corners of a square as shown in the figure. Each charge has the identical value +Q. The length of the diagonal of the square is 2a.

17. The first two charges are brought from infinity and placed at adjacent corners. What is the electric potential energy of these two charges?

(a) $\dfrac{kQ^2}{a\sqrt{2}}$ (b) $\dfrac{2kQ}{a}$ (c) $\dfrac{kQ}{a\sqrt{2}}$ (d) $\dfrac{kQ^2}{2a}$ (e) $\dfrac{kQ^2}{4a}$

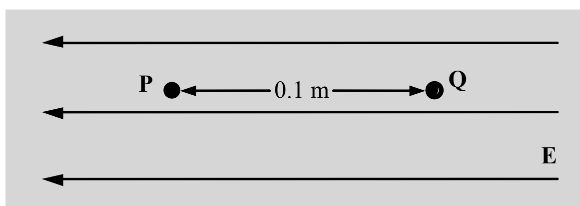
18. What is the magnitude of the electric field at **P**, the center of the square?

(a) kQ/a^2 (b) $2kQ/a^2$ (c) $4kQ/a^2$ (d) $kQ/4a^2$ (e) zero V/m

19. What is the electric potential at **P**, the center of the square?

(a) kQ/a (b) $2kQ/a$ (c) $4kQ/a$ (d) $kQ/4a$ (e) zero volts

Questions 20 and 21 refer to the following statement and figure:



P and **Q** are points within a uniform electric field that are separated by a distance of 0.1 m as shown. The potential difference between **P** and **Q** is 50 V.

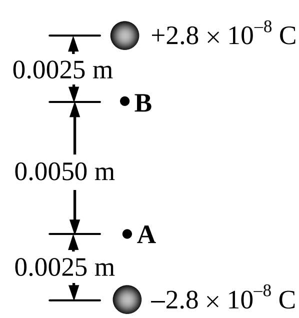
20. Determine the magnitude of this electric field.

(a) 0.5 V/m (b) 5.0 V/m (c) 50 V/m (d) 500 V/m (e) 5000 V/m

21. How much work is required to move a +1000 μC point charge from **P** to **Q**?

(a) 0.02 J (b) 0.05 J (c) 200 J (d) 1000 J (e) 5000 J

Questions 22 and 23 pertain to the following situation:



Two point charges are separated by 1.00×10^{-2} m. One charge is -2.8×10^{-8} C; and the other is $+2.8 \times 10^{-8}$ C. The points **A** and **B** are located 2.5×10^{-3} m from the lower and upper point charges as shown.

22. If an electron, which has a charge of 1.60×10^{-19} C, is moved from rest at A to rest at B, what is the change in electric potential energy of the electron?

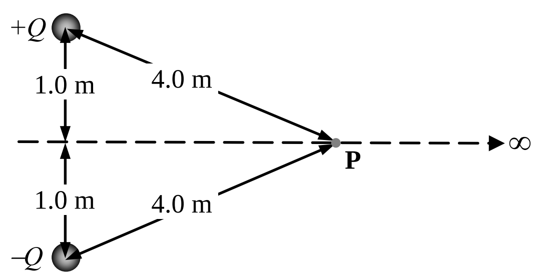
(a) $+4.3 \times 10^{-15}$ J (c) -2.1×10^{-14} J

(e) zero joules
(b) $+5.4 \times 10^{-15}$ J (d) -3.2×10^{-14} J

23. If a proton, which has a charge of $+1.60 \times 10^{-19}$ C, is moved from rest at **A** to rest at **B**, what is change in electrical potential energy of the proton?
(a) $+2.1 \times 10^{-14}$ J (c) -4.3×10^{-15} J (e) zero joules
(b) $+3.2 \times 10^{-14}$ J (d) -5.4×10^{-15} J

Questions 24 through 26 pertain to the situation described below:

Two charges of opposite sign and equal magnitude Q = 2.0 C are held 2.0 m apart as shown in the figure.



24. Determine the magnitude of the electric field at the point **P**.
(a) 2.2×10^{9} V/m (c) 4.4×10^{8} V/m (e) zero V/m
(b) 5.6×10^{8} V/m (d) 2.8×10^{8} V/m

25. Determine the electric potential at the point **P**.
(a) 1.1×10^{9} V (c) 4.5×10^{9} V (e) zero volts
(b) 2.2×10^{9} V (d) 9.0×10^{9} V

26. How much work is required to move a 1.0 C charge from infinity to the point **P**?
(a) zero joules (c) 4.5×10^{9} J (e) infinity
(b) 2.2×10^{9} J (d) 9.0×10^{9} J

Section 19.4 Equipotential Surfaces and Their Relation to the Electric Field

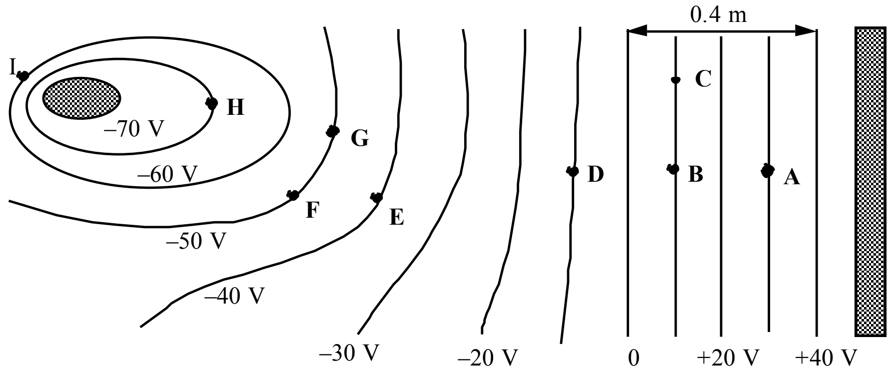
27. Which one of the following statements concerning electrostatic situations is false?
(a) **E** is zero everywhere inside a conductor.
(b) Equipotential surfaces are always perpendicular to **E**.
(c) Zero work is needed to move a charge along an equipotential surface.
(d) If V is constant throughout a *region of space*, then E must be zero in that region.
(e) No force component acts along the path of a charge as it is moved along an equipotential surface.

28. Which one of the following statements best describes the equipotential surfaces surrounding a point charge?
(a) The equipotential surfaces are planes extending radially outward from the charge.
(b) The equipotential surfaces are curved planes surrounding the charge, but only one passes through the charge.
(c) The equipotential surfaces are concentric cubes with the charge at the center.
(d) The equipotential surfaces are concentric spheres with the charge at the center.
(e) The equipotential surfaces are concentric cylinders with the charge on the axis at the center.

29. A charge is located at the center of sphere A (radius R_A = 0.0010 m), which is in the center of sphere B (radius R_B = 0.0012 m). Spheres A and B are both equipotential surfaces. What is the ratio V_A/V_B of the potentials of these surfaces?
(a) 0.42 (c) 1.2 (e) 2.4
(b) 0.83 (d) 1.4

Questions 30 through 38 refer to the statement and figure below:

The sketch below shows cross sections of equipotential surfaces between two charged conductors that are shown in solid grey. Various points on the equipotential surfaces near the conductors are labeled **A**, **B**, **C**, ..., **I**.



☐ 30. At which of the labeled points will the electric field have the greatest magnitude?
(a) **G** (b) **I** (c) **A** (d) **H** (e) **D**

◘ 31. At which of the labeled points will an electron have the greatest potential energy?
(a) **A** (b) **D** (c) **G** (d) **H** (e) **I**

☐ 32. What is the potential difference between points **B** and **E**?
(a) 10 V (b) 30 V (c) 40 V (d) 50 V (e) 60 V

◘ 33. What is the direction of the electric field at **B**?
(a) toward **A** (b) toward **D** (c) toward **C** (d) into the page (e) up and out of the page

◘ 34. How much work is required to move a –1.0 μC charge from **A** to **E**?
(a) $+3.0 \times 10^{-5}$ J (b) -4.0×10^{-5} J (c) $+7.0 \times 10^{-5}$ J (d) -7.0×10^{-5} J (e) zero joules

☐ 35. How much work is required to move a –1.0 μC charge from **B** to **D** to **C**?
(a) $+2.0 \times 10^{-5}$ J (b) -2.0×10^{-5} J (c) $+4.0 \times 10^{-5}$ J (d) -4.0×10^{-5} J (e) zero joules

☐ 36. A positive point charge is placed at **F.** Complete the following statement: When it is released,
(a) no force will be exerted on it.
(b) a force will cause it to move toward **E**.
(c) a force will cause it to move toward **G**.
(d) a force will cause it to move away from **E**.
(e) it would subsequently lose kinetic energy.

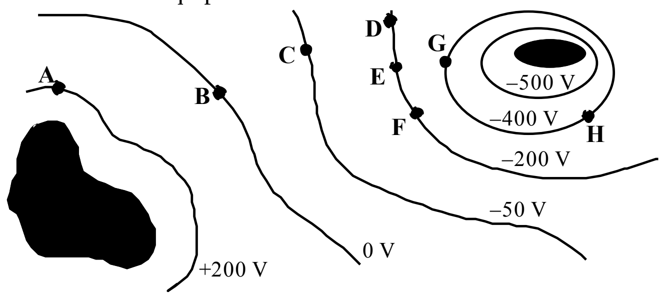
◘ 37. What is the magnitude of the electric field at point **A**?
(a) 10 V/m (b) 25 V/m (c) 30 V/m (d) 75 V/m (e) 100 V/m

◘ 38. A point charge gains 50 μJ of electric potential energy when it is moved from point **D** to point **G**. Determine the magnitude of the charge.
(a) 1.0 μC (c) 25 μC (e) 130 μC

(b) 1.3 μC (d) 50 μC

Questions 39 through 41 pertain to the following situation:

The sketch shows cross sections of equipotential surfaces between two charged conductors shown in solid black. Points on the equipotential surfaces near the conductors are labeled **A**, **B**, **C**, ..., **H**.



☐ 39. What is the magnitude of the potential difference between points **A** and **H**?
(a) 100 V (c) 400 V (e) 700 V
(b) 200 V (d) 600 V

◘ 40. What is the direction of the electric field at point **E**?
(a) toward **G** (c) toward **H** (e) toward **F**
(b) toward **B** (d) toward **C**

■ 41. How much work is required to move a +6.0 μC point charge from B to F to D to A?
(a) $+1.2 \times 10^{-3}$ J (c) $+3.6 \times 10^{-3}$ J (e) zero joules
(b) -1.2×10^{-3} J (d) -3.6×10^{-3} J

Section 19.5 Capacitors and Dielectrics
Section 19.6 Biomedical Applications of Electric Potential Differences

◘ 42. The magnitude of the charge on the plates of an *isolated* parallel plate capacitor is doubled. Which one of the following statements is true concerning the capacitance of this parallel-plate system?
(a) The capacitance is decreased to one half of its original value.
(b) The capacitance is increased to twice its original value.
(c) The capacitance remains unchanged.
(d) The capacitance depends on the electric field between the plates.
(e) The capacitance depends on the potential difference across the plates.

◘ 43. A parallel plate capacitor with plates of area A and plate separation d is charged so that the potential difference between its plates is V. If the capacitor is then isolated and its plate separation is decreased to $d/2$, what happens to the potential difference between the plates?
(a) The final potential difference is $4V$.
(b) The final potential difference is $2V$.
(c) The final potential difference is $0.5V$.
(d) The final potential difference is $0.25V$.
(e) The final potential difference is V.

◘ 44. A parallel plate capacitor with plates of area A and plate separation d is charged so that the potential difference between its plates is V. If the capacitor is then isolated and its plate separation is decreased to $d/2$, what happens to its capacitance?
(a) The capacitance is twice its original value.

(b) The capacitance is four times its original value.
(c) The capacitance is eight times its original value.
(d) The capacitance is one half of its original value.
(e) The capacitance is unchanged.

■ 45. A parallel plate capacitor is fully charged at a potential *V*. A dielectric with constant $\kappa = 4$ is inserted between the plates of the capacitor while the potential difference between the plates remains constant. Which one of the following statements is false concerning this situation?
(a) The energy density remains unchanged.
(b) The capacitance increases by a factor of four.
(c) The stored energy increases by a factor of four.
(d) The charge on the capacitor increases by a factor of four.
(e) The electric field between the plates increases by a factor of four.

◘ 46. Which one of the following changes will necessarily increase the capacitance of a capacitor?
(a) decreasing the charge on the plates
(b) increasing the charge on the plates
(c) placing a dielectric between the plates
(d) increasing the potential difference between the plates
(e) decreasing the potential difference between the plates

◘ 47. Complete the following statement: When a dielectric with constant κ is inserted between the plates of a charged *isolated* capacitor
(a) the capacitance is reduced by a factor κ.
(b) the charge on the plates is reduced by a factor of κ.
(c) the charge on the plates is increased by a factor of κ.
(d) the electric field between the plates is reduced by a factor of κ.
(e) the potential difference between the plates is increased by a factor of κ.

◘ 48. A parallel plate capacitor has a potential difference between its plates of 1.2 V and a plate separation distance of 2.0 mm. What is the magnitude of the electric field if a material that has a dielectric constant of 3.3 is inserted between the plates?
(a) 75 V/m
(b) 180 V/m
(c) 250 V/m
(d) 400 V/m
(e) 500 V/m

◘ 49. A capacitor has a very large capacitance of 10 F. The capacitor is charged by placing a potential difference of 2 V between its plates. How much energy is stored in the capacitor?
(a) 2000 J
(b) 500 J
(c) 100 J
(d) 40 J
(e) 20 J

◘ 50. The effective area of each plate of a parallel plate capacitor is 2.4 m^2. The capacitor is filled with neoprene rubber ($\kappa = 6.4$). When a 3.0-V potential difference exists across the plates of the capacitor, the capacitor stores 5.0 μC of charge. Determine the plate separation of the capacitor.
(a) 7.2×10^{-5} m
(b) 3.0×10^{-4} m
(c) 1.7×10^{-4} m
(d) 5.3×10^{-4} m
(e) 8.2×10^{-5} m

◘ 51. A uniform electric field of 8 V/m exists between the plates of a parallel plate capacitor. How much work is required to move a +20 μC point charge from the negative plate to the positive plate if the plate separation is 0.050 m?
(a) 0.4 J
(c) 8×10^{-4} J
(e) 8×10^{-6} J

(b) 1.6 J
(d) 8×10^{-5} J

◘ 52. A capacitor is initially charged to 2 V. It is then connected to a 4 V battery. What is the ratio of the final to the initial energy stored in the capacitor?
(a) 2
(b) 4
(c) 6
(d) 8
(e) 10

◘ 53. A parallel plate capacitor has plates of area 2.0×10^{-3} m^2 and plate separation 1.0×10^{-4} m. Determine the capacitance of this system if air fills the volume between the plates.
(a) 1.1×10^{-10} F
(b) 1.8×10^{-10} F
(c) 3.2×10^{-10} F
(d) 4.4×10^{-10} F
(e) 5.3×10^{-10} F

◘ 54. A parallel plate capacitor has plates of area 2.0×10^{-3} m^2 and plate separation 1.0×10^{-4} m. Air fills the volume between the plates. What potential difference is required to establish a 3.0 μC charge on the plates?
(a) 9.3×10^{2} V
(b) 2.4×10^{4} V
(c) 1.7×10^{4} V
(d) 6.9×10^{3} V
(e) 3.7×10^{5} V

◘ 55. A potential difference of 120 V is established between two parallel metal plates. The magnitude of the charge on each plate is 0.020 C. What is the capacitance of this capacitor?
(a) 170 μC
(b) 24 μC
(c) 7.2 μC
(d) 0.12 C
(e) 2.4 C

Questions 56 through 61 pertain to the situation described below:

The plates of a parallel plate capacitor each have an area of 0.40 m^2 and are separated by a distance of 0.02 m. They are charged until the potential difference between the plates is 3000 V. The charged capacitor is then isolated.

☐ 56. Determine the magnitude of the electric field between the capacitor plates.
(a) 60 V/m
(b) 120 V/m
(c) 1.0×10^{5} V/m
(d) 1.5×10^{5} V/m
(e) 3.0×10^{5} V/m

◘ 57. Determine the value of the capacitance.
(a) 9.0×10^{-11} F
(b) 1.8×10^{-10} F
(c) 3.6×10^{-10} F
(d) 4.8×10^{-10} F
(e) 6.4×10^{-10} F

◘ 58. Determine the magnitude of the charge on either capacitor plate.
(a) 1.8×10^{-7} C
(b) 2.7×10^{-7} C
(c) 4.9×10^{-7} C
(d) 5.4×10^{-7} C
(e) 6.8×10^{-7} C

◘ 59. How much work is required to move a –4.0 μC charge from the negative plate to the positive plate of this system?
(a) -1.2×10^{-2} J
(b) $+1.2 \times 10^{-2}$ J
(c) -2.4×10^{-2} J
(d) $+2.4 \times 10^{-2}$ J
(e) -5.4×10^{-2} J

■ 60. Suppose that a dielectric sheet is inserted to completely fill the space between the plates and the potential difference between the plates drops to 1000 V. What is the capacitance of the system after the dielectric is inserted?
(a) 1.8×10^{-10} F
(c) 5.4×10^{-10} F
(e) 6.8×10^{-10} F

(b) 2.7×10^{-10} F (d) 6.2×10^{-10} F