EXERCISES

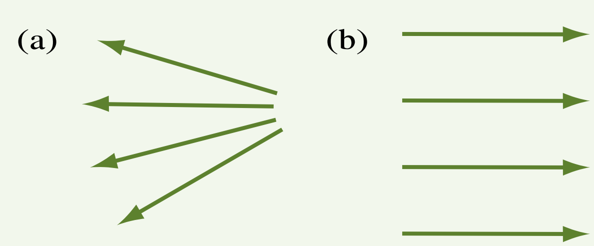
Conceptual Questions

1. Explain why a neutral object can be attracted to a charged object. Why can this neutral object not be repelled by a charged object?
2. What is the function of an electroscope?
3. When you rub a balloon against your hair on a dry day, you can stick the balloon to the ceiling. Explain what happens in terms of charge separation, using a diagram.
4. When two substances, such as acetate and silk, are rubbed together, electrons move from one substance to the other. Explain what happens in terms of basic atomic theory.
5. A new solid material is being tested for its electrostatic properties. Describe how you would test this material to determine its place in an updated electrostatic series.
6. A computer technician always touches the metal body of a computer before touching any of its electronic parts. Why? Explain using your knowledge of electrostatics.
7. Use the table below to compare and contrast Newton's universal law of gravitation and Coulomb's law.

Criterion	Newton's law of universal gravitation	Coulomb's law
Equation		
Constant of proportionality		
Type of force(s)		
Conditions for use		

8. Why can't electric field lines cross?
9. In which direction do charges always move in an electric field?
10. An insulating rod has a charge of $+q$ at one end and a charge of $-q$ at the other end. What will the rod tend to do when placed inside a uniform electric field oriented
a) perpendicular to the rod?
b) parallel to the rod?
11. Eight negative point charges of equal magnitude are distributed evenly around a circle. Sketch the electric field in the region around and within this charge distribution. Explain how this charge distribution can be used to model the electric field inside a coaxial cable.
12. If a test charge is moved from one area in an electric field to another area along an equipotential line, how much work is done on the charge? If a constant force is applied to move the test charge, what happens to the charge's speed?
13. Why do we use the term "point charge" when studying electric fields? How would our study be affected if we used charged bodies with large dimensions?
14. Figure 8.51 shows two sets of electric field lines. Use a table like the one below or another means of recording your answer to summarize the given true-or-false statements. Explain your reasoning in each case.

Fig.8.51



Statement	True?	False?	Reasoning
In each case the field gets stronger as you proceed from left to right.			
The field strength in (a) increases from left to right but in (b) it remains the same everywhere.			
Both fields could be created by a series of positive charges on the left and negative ones on the left.			
Both fields could be created by a single positive point charge placed on the right.			

15. Although there are similarities between electric and gravitational fields, electric fields are more complicated to work with. Support this statement with evidence from the textbook.

16. Describe the field shape around a single negative point charge.

17. If you were to double the magnitude of a test charge used to map an electric field, what would happen to the strength of the electric field that you were mapping?

18. How can you tell the difference between a weak electric field and a strong electric field?

19. Compare and contrast the various aspects of an electric field and a gravitational field.

20. What is the direction of an electric field between a positive and a negative charge?

21. Explain why the electric potential energy between two like charges is greater than for two unlike charges the same distance apart.

22. If a high-voltage wire falls onto a car, will the people inside be safe from electrocution? Under what conditions would electrocution not occur?

23. When a parallel-plate apparatus is connected to a power supply, one plate becomes positively charged and the other plate becomes negatively charged. What is the net charge on the apparatus? Explain your answer.

24. What would happen to the uniform field strength inside a parallel-plate capacitor if the following changes were made independently of each other?
    a) The distance between the plates is doubled.
    b) The charge on each plate is doubled.
    c) The plates are totally discharged and neutral.

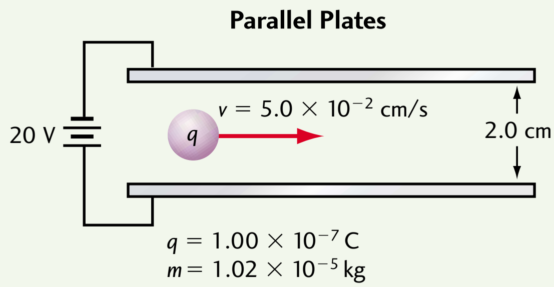
25. What point charges of similar magnitude should be placed side by side so that both the electric field strength and the potential are zero at the midpoint of the distance between them? Where would the field strength and potential be zero if one of the two charges was twice the magnitude of the other?

26. No electric field means a field strength and a potential of zero. Use your discussion of question 25 to describe the conditions necessary for both the field strength and the potential to be zero at a point in the presence of electric fields.

27. A proton and an electron are released from rest a distance apart and allowed to accelerate toward each other. Just before collision, which particle is travelling faster? Explain.

28. A parallel-plate capacitor is mounted horizontally and a charge is released into it at a constant speed of 5.0×10^{-2} cm/s, as shown in Figure 8.52.

Fig.8.52

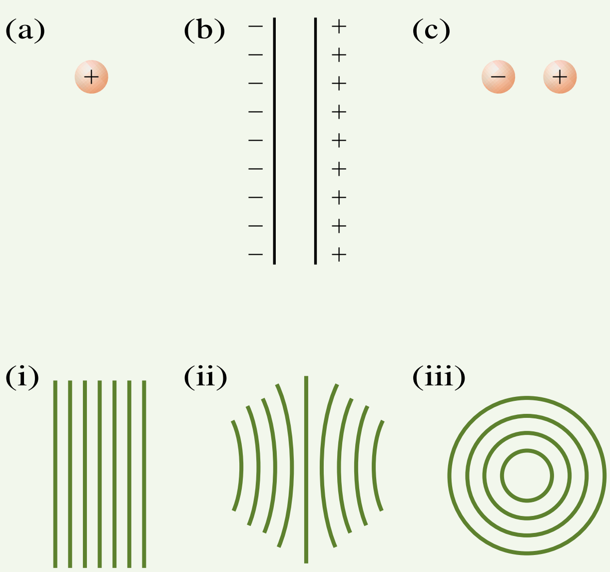


In your notebook, sketch the path of the moving charge as it passes between the plates. Where do we see this type of motion around us?

29. Does a parallel-plate capacitor have uniform potential as well as field strength? If not, is there any path that a charge can take where the potential is uniform (does not change)? If so, what is the path called?

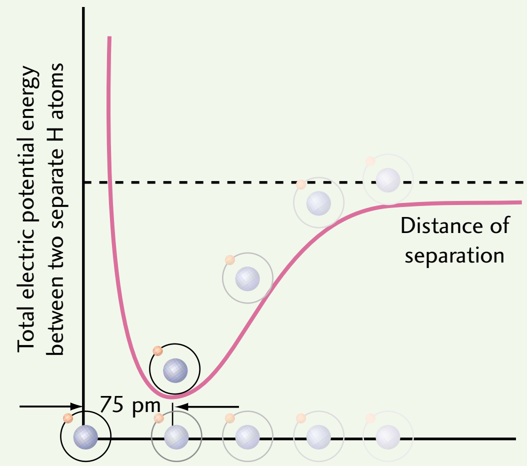
30. Match each charge distribution in Figure 8.53 with the appropriate set of equipotential lines below. Use the equipotential lines as clues to drawing the field lines for each charge distribution.

Fig.8.53



31. One of the simplest chemical bonds is a covalent bond between two hydrogen atoms to make the molecule H_2. Figure 8.54 illustrates the electric potential energy between two separate hydrogen atoms.

Fig.8.54



a) What electrostatic interactions cause the large increase in E_e when the two nuclei are brought very close together?

b) Why does this increase in E_e cause design problems for engineers in the nuclear energy industry?

c) Pushing these atoms together increases their potential energy, but so does pulling them apart. What electrostatic interactions cause this smaller increase in E_e?

d) How would you use the concepts of potential energy and forces to explain why two hydrogen atoms can form a stable bond at a distance of 75 pm apart?

32. A potential-energy curve is like a topographic map of a mountain or valley road that a charge could "roll" on. What topography would be analogous to a positive test charge moving along a line between two identical negative point charges? How would the topography change

a) if the two point charges were positive?

b) if a negative test charge was placed between these two charges?

Problems

8.2 The Basis of Electric Charge — The Atom

33. Which part of the atom is represented by positive signs? by negative signs?

34. What is the charge on each of the following?
    a) A neutral oxygen atom
    b) An electron
    c) A nucleus
    d) A neutron
    e) A proton

8.3 Electric Charge Transfer

35. State which of the two items listed below is left with an overall positive or negative charge:
    a) A piece of rubber rubbed with silk
    b) The silk from part a)
    c) An acetate sheet rubbed with cat's fur
    d) Glass rubbed with wool

36. A piece of amber is rubbed with fur.
    a) What type of charge is on the amber?
    b) What particles are transferred between the amber and the fur?

37. A suspended glass rod is rubbed with a piece of silk.
    a) What type of charge is on each material after rubbing?
    b) What happens if the silk is brought close to the glass rod?

38. State whether each of the following is an electric conductor or an insulator. Give a reason for your answer.
    a) Plastic food wrap
    b) A lightning rod
    c) A plastic comb
    d) A party balloon stuck to a wall
    e) A car's tire during a lightning storm
    f) The rubber belt on a Van de Graaff electrostatic generator

39. A silk shirt is removed from a clothes dryer along with several pairs of wool socks. If the shirt attracts loose dog hair, what is the charge on the dog hair?

40. A metal-leaf electroscope is touched by a positively charged rod.
    a) What is the charge on the electroscope? Explain how the electroscope got this charge. What phenomenon causes this process to occur?
    b) What happens to the leaf (or leaves) of the electroscope? Explain.
    c) What happens to the leaves of the electroscope if the system is grounded?

41. A wire passes a charge of 15.0 C. How many electrons pass through the wire?

42. Small charges are measured in microcoulombs (μC). A shock of 1.1 μC is passed from one student to another in a dry physics classroom. How many electrons were transferred?

43. What is the charge on an electroscope that has a deficit of 4.0×10^{11} electrons?

44. A metal ball with a charge of 5.4×10^{8} electrons is touched to another metal ball so that all the excess electrons are shared equally. What is the final charge on the first ball?

45. A nucleus has a charge of $+2.4 \times 10^{-12}$ C. How many electrons does this neutral atom have?

8.4 Coulomb's Law

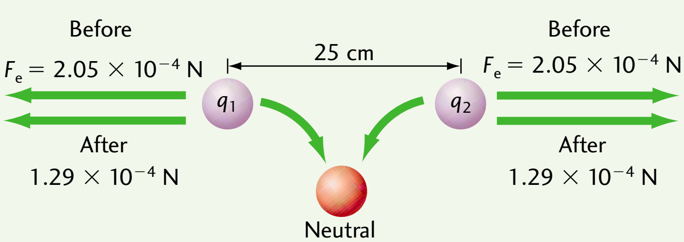
46. Two small oppositely charged spheres experience a force of attraction of 1.4×10^{-2} N. What would happen to this force if
    a) the distance between the charges is quadrupled?
    b) the magnitude of the charge on each is doubled?
    c) both (a) and (b) occurred simultaneously?

47. Two small, similarly charged foam spheres experience a force F_{e_1} when separated by a distance r_1. Both spheres are touched with identical, electrically neutral spheres that are then removed. Where must these two spheres be moved in relation to each other in order to regain their initial force of repulsion?

48. What force of repulsion exists between two electrons in a molecule that are 100 pm apart? (The charge on an electron is 1.602×10^{-19} C.)

49. Two small, identical foam spheres repel each other with a force of 2.05×10^{-4} N when they are 25.0 cm apart. Both spheres are forced to touch an identical, neutral third sphere that is then removed (see Figure 8.55). The two charged spheres now experience a force of 1.29×10^{-4} N when returned to their initial 25.0-cm separation.

Fig.8.55



a) What is the charge on each sphere after contact with the neutral sphere?
b) What was the initial charge on each sphere before touching the neutral sphere? Does it matter if the charge is positive or negative?

50. Two small, identical spheres, with an initial charge of $+q$ and $-3q$, respectively, attract each other with a force of F_{e_1} when held a distance r apart. The two spheres are allowed to touch and are then drawn apart to the distance r. Now they repel with a force of F_{e_2}. Find the ratio $\frac{F_{e_2}}{F_{e_1}}$ of the two forces. Describe what this ratio means in terms of magnitude and direction of the two forces, F_{e_1} and F_{e_2}.

51. A stationary proton holds an electron in suspension underneath it against the force of gravity ($m_{electron} = 9.1 \times 10^{-31}$ kg).
a) Draw a free-body diagram of this situation.
b) How far below the proton would the electron be suspended?

52. A point charge of $+3.8 \times 10^{-6}$ C is placed 0.20 m to the right of a charge of -2.0×10^{-6} C. What is the force on a third charge of $+2.3 \times 10^{-6}$ C if it is placed
a) 0.10 m to the left of the first charge?
b) 0.10 m to the right of the second charge?
c) halfway between the first two charges?
d) Where would the third charge experience a net force of zero?

53. Prove that a charge of $+q$ would come to rest with no net force on it $\frac{1}{3}$ of the way between two charges, $+q$ and $+4q$, that are held some distance apart.

54. Three charges of $+1.0 \times 10^{-4}$ C form an equilateral triangle with side length 40 cm. What is the magnitude and direction of the electric force on each charge?

55. A square with side length 2.0 cm has a charge of -1.0×10^{-6} C at every corner.
a) What is the magnitude and direction of the electric force on each charge? (Hint: Use the symmetry of the figure to simplify the problem.)
b) What is the force on a fifth charge placed in the centre of this square?
c) Does the sign of the fifth charge affect the magnitude or direction of force on it?

8.5 Fields and Field-mapping Point Charges

56. In your notebook, draw two small circles, about 5 cm apart, and label them with positive (+) signs. Use the concept of placing test charges on the page to map what the electric field around these charges would look like.

57. How would the field map in problem 56 change if the charge on the left was tripled?

58. In your notebook, draw two parallel lines representing metal plates, one positive and one negative, and a circle (negative) with a positive conductor in the centre (coaxial cable). Map the electric field around the two plate configurations.

8.6 Field Strength

59. A positive charge of 2.2×10^{-6} C experiences a force of 0.40 N at a distance r from another charge, q_m. What is the field strength at this position?

60. What is the magnitude of a test charge that experiences a force of 3.71 N in a field of strength 170 N/C?

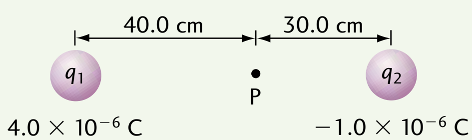
61. Two charges of $+4.0 \times 10^{-6}$ C and $+8.0 \times 10^{-6}$ C are placed 2.0 m apart. What is the field strength halfway between them?

62. A point charge of 2.0×10^{-6} C experiences an electric force of 7.5 N to the left.
    a) What is the electric field strength at this point?
    b) What force would be exerted on a -4.9×10^{-5} C charge placed at the same spot?

63. What is the electric field strength (magnitude and direction) 0.5 m to the left of a point charge of 1.0×10^{-2} C?

64. What is the electric field strength (magnitude and direction) at point P between the two charges in Figure 8.56?

Fig.8.56



65. In a hydrogen atom, the electron and the proton are separated by an average distance of 5.3×10^{-11} m. What is the field strength from the proton at the position of the electron?

66. Two charges of $+1.5 \times 10^{-6}$ C and $+3.0 \times 10^{-6}$ C are 0.20 m apart. Where is the electric field between them equal to zero?

67. Four charges of $+1.0 \times 10^{-6}$ C are at the corners of a square with sides of length 0.5 m. Find the electric field strength at the centre of the square.

68. What is the electric field strength at the vertex of an equilateral triangle with sides of 0.50 m if the charges at the other vertices are $+2.0 \times 10^{-5}$ C?

8.7 Electric Potential and Electric Potential Energy

69. A particle with a charge magnitude 0.50 C is accelerated through a potential difference of 12 V. How much work is done on the particle?

70. A 6.0-V battery does 7.0×10^2 J of work while transferring charge to a circuit. How much charge does the circuit transfer?

71. A charge of 1.50×10^{-2} C experiences a force of 7.50×10^3 N over a distance of 4.50 cm. What is the potential difference between the initial and final position of the charge?

72. How much work is done by a system in which a field strength of 130 N/C provides a force of 65 N through a potential difference of 450 V?

73. What is the electric potential 0.30 m from a point charge of $+6.4 \times 10^{-6}$ C?

74. A small mobile test charge of magnitude -1.0×10^{-6} C is forced toward a stationary charge of -5.0×10^{-6} C.
    a) How much electric potential energy does the test charge have 0.25 m away from the stationary charge?

b) How much work was done on the charge to move it from an original distance of 1.00 m away?

8.8 Movement of Charged Particles in a Field — The Conservation of Energy

75. What is the electric potential two-fifths of the way through a parallel-plate apparatus (from the positive plate) if the plates have a total separation of 5.0 cm and a field strength of 5.0×10^3 N/C?

76. A particle carrying a charge of 10^{-5} C starts moving from rest in a uniform electric field of intensity 50 N/C.
a) What is the force applied to the particle?
b) How much kinetic energy does the particle have after it has moved 1.0 m?
c) If the particle's speed is 2.5×10^4 m/s at this point, what is its mass?

77. Two electrons are 10^{-9} m apart when they are released. What is their speed when they are 10^{-8} m apart?

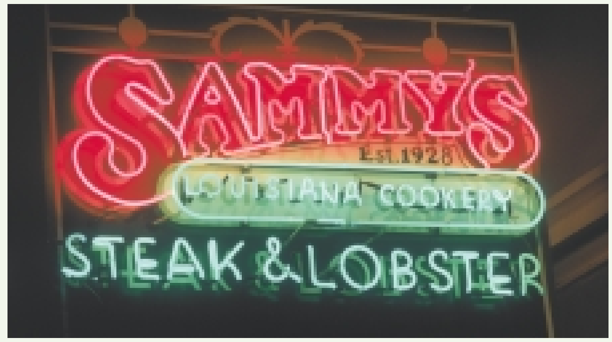
78. How does doubling the accelerating voltage of the electron gun in a cathode ray tube affect the speed of the electrons that reach the screen?

79. The electron gun of a TV picture tube has an accelerating potential difference of 15 kV and a power rating of 27 W.
a) How many electrons reach the screen per second?
b) What speed does each electron have?

80. The electrodes in a neon sign (Figure 8.57) are 1.2 m apart and the potential difference across them is 7.5×10^3 V.

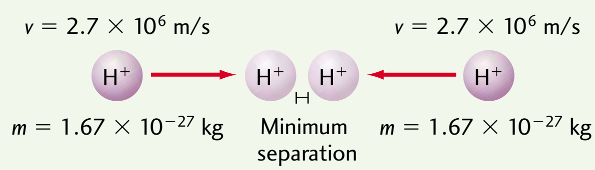
a) What is the acceleration of charge ($+e$) of a neon ion of mass 3.3×10^{-26} kg in the field?
b) How much energy does the ion gain if it is released from a positive electrode and accelerates directly to the negative electrode?
c) Do you think an ion would really gain this much energy? Explain your reasoning.

Fig.8.57



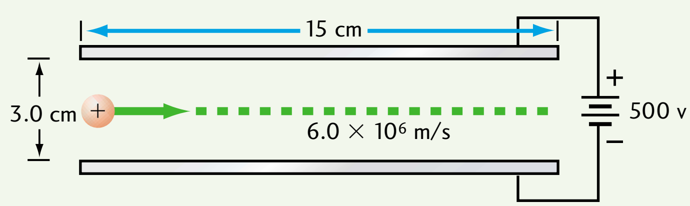
81. To start a nuclear fusion reaction, two hydrogen atoms of charge $+1e$ and mass 1.67×10^{-27} kg must be fired at each other. If each particle has an initial velocity of 2.7×10^6 m/s (Figure 8.58) when released, what is their minimum separation?

Fig.8.58



82. An alpha particle with a speed of 6.0×10^6 m/s enters a parallel-plate apparatus that is 15 cm long and 3.0 cm wide, with a potential difference of 500 V (see Figure 8.59).

Fig.8.59



a) How close is the particle to the lower plate when it emerges from the other side?
b) What is the magnitude of the velocity of the alpha particle as it leaves the plates? (Hint: Find the vertical and horizontal components of velocity first.)

8.9 The Electric Field Strength of a Parallel-plate Apparatus

83. A set of parallel plates, separated by a distance of 0.050 m, has a potential difference of 39.0 V. What is the field strength?

84. The electric field strength between two plates 6.35 cm apart is 2.85×10^4 N/C. What is the potential difference between them?

85. a) How strong an electric field is required to support an alpha particle (a 2+ charged helium nucleus with two protons and two neutrons) against the force of gravity? ($m_{proton} \approx m_{neutron} = 1.67 \times 10^{-27}$ kg)
    b) If the alpha particle is suspended between a set of parallel plates 3.0 cm apart, what potential must be provided across the plates?

86. What is the electric field strength of a parallel-plate apparatus that has a plate separation of 0.12 m and a potential difference of 92 V?

87. An electric field stronger than 3×10^6 N/C causes a spark in air. What maximum potential difference can be applied across two metal plates 1.0×10^{-3} m apart before sparking begins?

88. A potential difference of 50 V is applied across two parallel plates, producing an electric field strength of 10^4 N/C. How far apart are the plates?

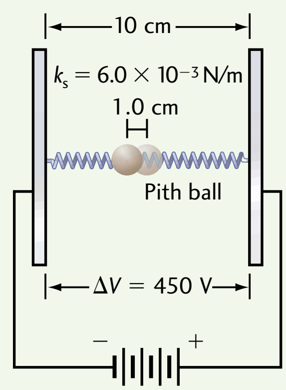
89. The potential difference applied to an adjustable parallel-plate capacitor is 120 V. What is the plate separation if the field strength is 450 N/C?

90. An oil droplet of mass 2.2×10^{-15} kg is suspended between two horizontal parallel plates that are 0.55 cm apart. If a potential difference of 280 V is applied,
    a) what is the charge on the droplet?
    b) how many electrons, in excess or deficit, does the droplet have?

91. An electron is released from rest from the negative plate of a parallel-plate apparatus.
    a) At what speed will the electron hit the positive plate if a 450-V potential difference is applied?
    b) What is the electron's speed one-third of the way between the plates?

92. A foam pith ball is supported by two small springs ($k = 6.0 \times 10^{-3}$ N/m) between two vertical parallel plates 10 cm apart, as shown in Figure 8.60. When the potential across the plates is 450 V, the pith ball moves 1.0 cm to the right before coming to rest. Ignoring any effects due to gravity and friction,

Fig.8.60



    a) what is the field strength between the two plates?
    b) what force changes the length of the two springs?
    c) what is the magnitude of the force acting on the foam pith ball?
    d) what is the charge on the pith ball?