MisConceptual Questions

1. $Q_1 = -0.10$ μC is located at the origin. $Q_2 = +0.10$ μC is located on the positive x axis at $x = 1.0$ m. Which of the following is true of the force on Q_1 due to Q_2?
   a. It is attractive and directed in the $+x$ direction.
   b. It is attractive and directed in the $-x$ direction.
   c. It is repulsive and directed in the $+x$ direction.
   d. It is repulsive and directed in the $-x$ direction.

2. Swap the positions of Q_1 and Q_2 of MisConceptual Question 1. Which of the following is true of the force on Q_1 due to Q_2?
   a. It does not change.
   b. It changes from attractive to repulsive.
   c. It changes from repulsive to attractive.
   d. It changes from the $+x$ direction to the $-x$ direction.
   e. It changes from the $-x$ direction to the $+x$ direction.

3. Fred the lightning bug has a mass m and a charge $+q$. Jane, his lightning-bug wife, has a mass of $\frac{3}{4}m$ and a charge $-2q$. Because they have charges of opposite sign, they are attracted to each other. Which is attracted more to the other, and by how much?
   a. Fred, twice as much.
   b. Jane, twice as much.
   c. Fred, four times as much.
   d. Jane, four times as much.
   e. They are attracted to each other by the same amount.

4. **Figure 16–50** shows electric field lines due to a point charge. What can you

say about the field at point 1 compared with the field at point 2?

a. The field at point 2 is larger, because point 2 is on a field line.
b. The field at point 1 is larger, because point 1 is not on a field line.
c. The field at point 1 is zero, because point 1 is not on a field line.
d. The field at point 1 is larger, because the field lines are closer together in that region.

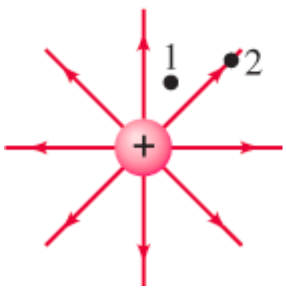

Figure 16–50

MisConceptual Question 4.

5. A negative point charge is in an electric field created by a positive point charge. Which of the following is true?
    a. The field points toward the positive charge, and the force on the negative charge is in the same direction as the field.
    b. The field points toward the positive charge, and the force on the negative charge is in the opposite direction to the field.
    c. The field points away from the positive charge, and the force on the negative charge is in the same direction as the field.
    d. The field points away from the positive charge, and the force on the negative charge is in the opposite direction to the field.

6. As an object acquires a positive charge, its mass usually
    a. decreases.
    b. increases.
    c. stays the same.
    d. becomes negative.

7. Refer to **Fig. 16–32d** . If the two charged plates were moved until they are half the distance shown without changing the charge on the plates, the electric field near the center of the plates would
   a. remain almost exactly the same.
   b. increase by a factor of 2.
   c. increase, but not by a factor of 2.
   d. decrease by a factor of 2.
   e. decrease, but not by a factor of 2.

8. We wish to determine the electric field at a point near a positively charged metal sphere (a good conductor). We do so by bringing a small positive test charge, q_0, to this point and measure the force F_0 on it. F_0/q_0 will be _____ the electric field

   $\vec{E}$ as it was at that point before the test charge was present.

   a. greater than
   b. less than
   c. equal to

9. We are usually not aware of the electric force acting between two everyday objects because
   a. the electric force is one of the weakest forces in nature.
   b. the electric force is due to microscopic-sized particles such as electrons and protons.
   c. the electric force is invisible.
   d. most everyday objects have as many plus charges as minus charges.

10. To be safe during a lightning storm, it is best to be
   a. in the middle of a grassy meadow.
   b. inside a metal car.
   c. next to a tall tree in a forest.
   d. inside a wooden building.

e. on a metal observation tower.

11. Which are the worst places in MisConceptual Question 10? **a, c**

12. Which vector best represents the direction of the electric field at the fourth corner of the square due to the three charges shown in **Fig. 16–51** ?

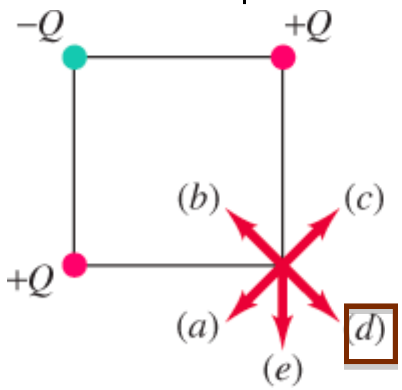

Figure 16–51

MisConceptual Question 12.

13. A small metal ball hangs from the ceiling by an insulating thread. The ball is attracted to a positively charged rod held near the ball. The charge of the ball must be

a. positive.
b. negative.
c. neutral.
d. positive or neutral.
e. negative or neutral.

For assigned homework and other learning materials, go to the MasteringPhysics website.

Problems

16–5 and 16–6 Coulomb's Law

[1 mc = 10^{-3}C, 1 μC = 10^{-6}C, 1 nC = 10^{-9}C.]

1. (I) What is the magnitude of the electric force of attraction between an iron nucleus (q = + 26e) and its innermost electron if the distance between them is 1.5×10^{-12} m? **0.003N**
2. (I) How many electrons make up a charge of –48.0 μC? **3 X 10^14**
3. (I) What is the magnitude of the force a +25 μC charge exerts on a +2.5 mC charge 16 cm away? **2.2 X 10^4 N**
4. (I) What is the repulsive electrical force between two protons 4.0×10^{-15} m apart from each other in an atomic nucleus? **14.4 N**
5. (II) When an object such as a plastic comb is charged by rubbing it with a cloth, the net charge is typically a few microcoulombs. If that charge is 3.0 μC, by what percentage does the mass of a 9.0-g comb change during charging?
6. (II) Two charged dust particles exert a force of 4.2×10^{-2} N on each other. What will be the force if they are moved so they are only one-eighth as far apart?
7. (II) Two small charged spheres are 6.52 cm apart. They are moved, and the force each exerts on the other is found to have tripled. How far apart are they now? **3.8 cm**
8. (II) A person scuffing her feet on a wool rug on a dry day accumulates a net charge of –28 μC. How many excess electrons does she get, and by how much does her mass increase? **1.75 X 10^14** **1.6 X 10^(-16) kg**
9. (II) What is the total charge of all the electrons in a 12-kg bar of gold? What is the net charge of the bar? (Gold has 79 electrons per atom and an atomic mass of 197 u.)
10. (II) Compare the electric force holding the electron in orbit (r = 0.53×10^{-10} m) around the proton nucleus of the

hydrogen atom, with the gravitational force between the same electron and proton. What is the ratio of these two forces?

FE=8.2 X 10^(-8) N
FG=3.6 X 10^(-47)
Ratio=2.2 X 10^39

11. (II) Particles of charge +65, +48, and −95 μC are placed in a line (**Fig. 16–52**). The center one is 0.35 m from each of the others. Calculate the net force on each charge due to the other two.

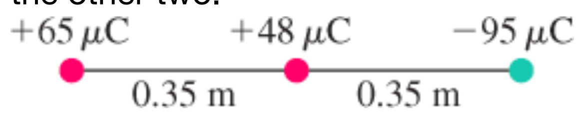

Figure 16–52

Problem 11.

12. (II) Three positive particles of equal charge, +17.0 μC, are located at the corners of an equilateral triangle of side 15.0 cm (**Fig. 16–53**). Calculate the magnitude and direction of the net force on each particle due to the other two.

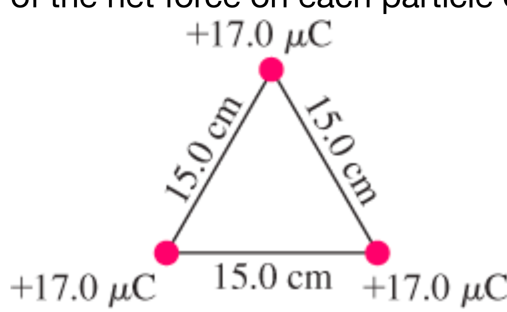

Figure 16–53

Problem 12.

13. (II) A charge *Q* is transferred from an initially uncharged plastic ball to an identical ball 24 cm away. The force of attraction is then 17 mN. How many electrons were transferred from one ball to the other?
14. (II) A charge of 6.15 mC is placed at each corner of a square 0.100 m on a side. Determine the magnitude and direction of the force on each charge.

15. (II) At each corner of a square of side ℓ there are point charges of magnitude Q, $2Q$, $3Q$, and $4Q$ (**Fig. 16–54**). Determine the magnitude and direction of the force on the charge $2Q$.

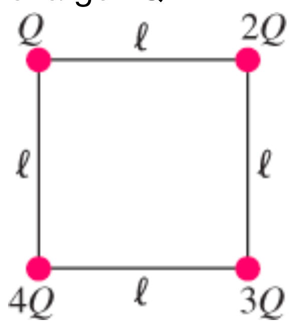

Figure 16–54

Problem 15.

16. (II) A large electroscope is made with “leaves” that are 78-cm-long wires with tiny 21-g spheres at the ends. When charged, nearly all the charge resides on the spheres. If the wires each make a 26° angle with the vertical (**Fig. 16–55**), what total charge Q must have been applied to the electroscope? Ignore the mass of the wires.

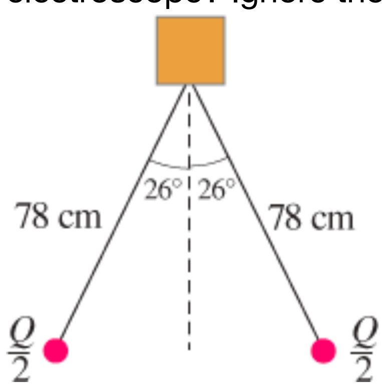

Figure 16–55

Problem 16.

17. (III) Two small nonconducting spheres have a total charge of 90.0 μC. (*a*) When placed 28.0 cm apart, the force each

exerts on the other is 12.0 N and is repulsive. What is the charge on each? (*b*) What if the force were attractive?

18. (III) Two charges, -*Q* and –3*Q*, are a distance ℓ apart. These two charges are free to move but do not because there is a third (fixed) charge nearby. What must be the magnitude of the third charge and its placement in order for the first two to be in equilibrium?

16–7 and 16–8 Electric Field, Field Lines

19. (I) Determine the magnitude and direction of the electric force on an electron in a uniform electric field of strength 2460 N/C that points due east. **3.9 X 10^(-16) N West**
20. (I) A proton is released in a uniform electric field, and it experiences an electric force of 1.86×10^{-14} N toward the south. Find the magnitude and direction of the electric field. **1.2 X 10^5 N/C South**
21. (I) Determine the magnitude and direction of the electric field 21.7 cm directly above an isolated 33.0×10^{-6} C charge. **6.3 X 10^6 N/C Up**
22. (I) A downward electric force of 6.4 N is exerted on a –7.3 μC charge. Find the magnitude and direction of the electric field at the position of this charge. **8.8 X 10^5 Up**
23. (II) Determine the magnitude of the acceleration experienced by an electron in an electric field of 756 N/C. How does the direction of the acceleration depend on the direction of the field at that point? **1.3 X 10^14 m/s' Opposite**
24. (II) Determine the magnitude and direction of the electric field at a point midway between a –8.0 μC and a +5.8 μC charge 6.0 cm apart. Assume no other charges are nearby. **1.4 X 10^8 N/C Toward neg**
25. (II) Draw, approximately, the electric field lines about two point charges, +*Q* and –3*Q*, which are a distance ℓ apart.

(II) What is the electric field strength at a point in space where a proton experiences an acceleration of 2.4 million "*g*'s"?

- (II) An electron is released from rest in a uniform electric field and accelerates to the north at a rate of 105 m/s^2. Find the magnitude and direction of the electric field.

- (II) The electric field midway between two equal but opposite point charges is 386 N/C, and the distance between the charges is 16.0 cm. What is the magnitude of the charge on each?

- (II) Calculate the electric field at one corner of a square 1.22 m on a side if the other three corners are occupied by 3.25×10^{-6} C charges.

- (II) Calculate the electric field at the center of a square 42.5 cm on a side if one corner is occupied by a –38.6 μC charge and the other three are occupied by –27.0 μC charges.

- (II) Determine the direction and magnitude of the electric field at the point P in Fig. 16–56. The charges are separated by a distance 2*a*, and point P is a distance *x* from the midpoint between the two charges. Express your answer in terms of *Q, x, a*, and *k*.

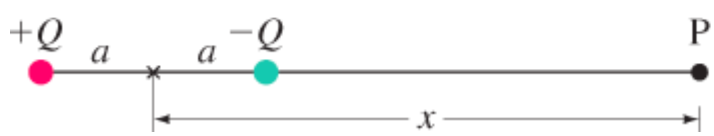

Figure 16–56

Problem 31.

- (II) Two point charges, $Q_1 = -32\ \mu C$ and $Q_2 = +45\ \mu C$, are separated by a distance of 12 cm. The electric field at the point P (see **Fig. 16–57**) is zero. How far from Q_1 is P?

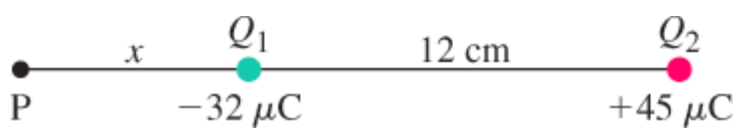

Figure 16–57
Problem 32.

- (II) Determine the electric field $\vec{E}$ at the origin 0 in **Fig. 16–58** due to the two charges at A and B.

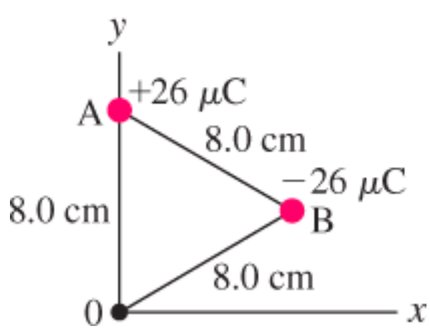

Figure 16–58
Problem 33.

- (II) You are given two unknown point charges, Q_1 and Q_2. At a point on the line joining them, one-third of the way from Q_1 to Q_2, the electric field is zero (**Fig. 16–59**). What is the ratio Q_1/Q_2?

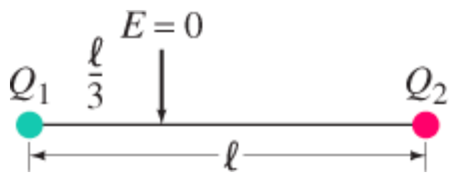

Figure 16–59

Problem 34.

- (III) Use Coulomb's law to determine the magnitude and direction of the electric field at points A and B in **Fig. 16–60** due to the two positive charges (Q = 4.7 μC) shown. Are your results consistent with **Fig. 16–32b** ?

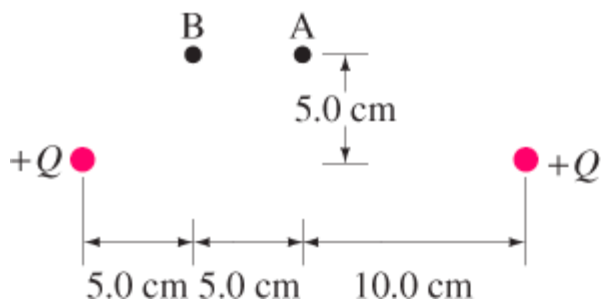

Figure 16–60

Problem 35.

- (III) An electron (mass m = 9.11 × 10 kg) is accelerated in the uniform field $\vec{E}$ (E = 1.45 × 10^4 N/C) between two thin parallel charged plates. The separation of the plates is 1.60 cm. The electron is accelerated from rest near the negative plate and passes through a tiny hole in the positive plate, **Fig. 16–61** . (*a*) With what speed does it leave the hole? (*b*) Show that the gravitational force can be ignored.

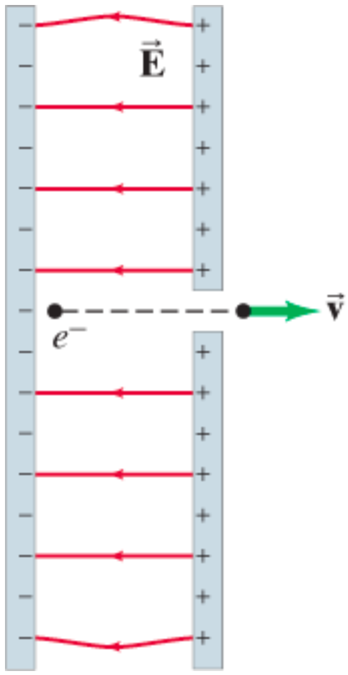

Figure 16–61
Problem 36.

*16–10 DNA

37. *(III) The two strands of the helix-shaped DNA molecule are held together by electrostatic forces as shown in **Fig. 16–39**. Assume that the net average charge (due to electron sharing) indicated on H and N atoms has magnitude $0.2e$ and on the indicated C and O atoms is $0.4e$. Assume also that atoms on each molecule are separated by 1.0×10^{-10} m. Estimate the net force between (*a*) a thymine and an adenine; and (*b*) a cytosine and a guanine. For each bond (red dots) consider only the three atoms in a line (two atoms on one molecule, one atom on the other). (*c*) Estimate the total force for a DNA molecule containing 10^5 pairs of such molecules. Assume half are A-T pairs and half are C-G pairs.

*16–12 Gauss's Law

38. *(I) The total electric flux from a cubical box of side 28.0 cm is $1.85 \times 10^3\ \text{N} \cdot \text{m}^2/\text{C}$. What charge is enclosed by the box?
39. *(II) In **Fig. 16–62**, two objects, O_1 and O_2, have charges +1.0 μC and –2.0 μC, respectively, and a third object, O_3, is electrically neutral. (*a*) What is the electric flux through the surface A_1 that encloses all three objects? (*b*) What is the electric flux through the surface A_2 that encloses the third object only?

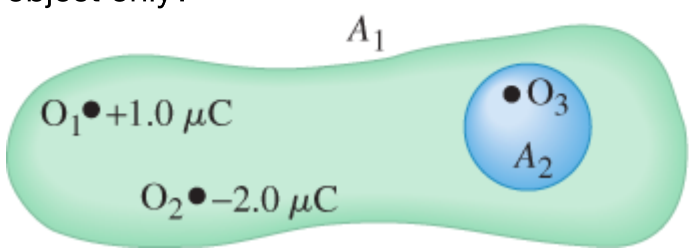

Figure 16–62
Problem 39.

40. *(II) A cube of side 8.50 cm is placed in a uniform field $E = 7.50 \times 10^3$ N/C with edges parallel to the field lines. (*a*) What is the net flux through the cube? (*b*) What is the flux through each of its six faces?
41. *(II) The electric field between two parallel square metal plates is 130 N/C. The plates are 0.85 m on a side and are separated by 3.0 cm. What is the charge on each plate (assume equal and opposite)? Neglect edge effects.
42. *(II) The field just outside a 3.50-cm-radius metal ball is 3.75×10^2 N/C and points toward the ball. What charge resides on the ball?
43. *(III) A point charge *Q* rests at the center of an uncharged thin spherical conducting shell. (See **Fig. 16–34**.) What is

the electric field E as a function of r (*a*) for r less than the inner radius of the shell, (*b*) inside the shell, and (*c*) beyond the shell? (*d*) How does the shell affect the field due to Q alone? How does the charge Q affect the shell?

General Problems

44. How close must two electrons be if the magnitude of the electric force between them is equal to the weight of either at the Earth's surface?
45. Given that the human body is mostly made of water, estimate the total amount of positive charge in a 75-kg person.
46. A 3.0-g copper penny has a net positive charge of 32 μC. What fraction of its electrons has it lost?
47. Measurements indicate that there is an electric field surrounding the Earth. Its magnitude is about 150 N/C at the Earth's surface and points inward toward the Earth's center. What is the magnitude of the electric charge on the Earth? Is it positive or negative? [*Hint:* The electric field outside a uniformly charged sphere is the same as if all the charge were concentrated at its center.]
48. (*a*) The electric field near the Earth's surface has magnitude of about 150 N/C. What is the acceleration experienced by an electron near the surface of the Earth? (*b*) What about a proton? (*c*) Calculate the ratio of each acceleration to g = 9.8 m/s^2.
49. A water droplet of radius 0.018 mm remains stationary in the air. If the downward-directed electric field of the Earth is 150 N/C, how many excess electron charges must the water droplet have?
50. Estimate the net force between the CO group and the HN group shown in **Fig. 16–63** . The C and O have charges ± 0.40e, and the H and N have charges +0.20e, where e = 1.6 × 10^{-19} C. [*Hint*: Do not include the “internal” forces between C and O, or between H and N.]

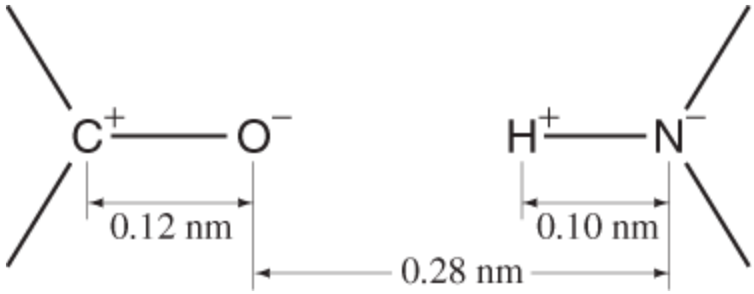

Figure 16–63

Problem 50.

51. In a simple model of the hydrogen atom, the electron revolves in a circular orbit around the proton with a speed of 2.2×10^6 m/s. Determine the radius of the electron's orbit. [*Hint:* See **Chapter 5** on circular motion.]
52. Two small charged spheres hang from cords of equal length ℓ as shown in **Fig. 16–64** and make small angles θ_1 and θ_2 with the vertical. (*a*) If $Q_1 = Q$, $Q_2 = 2Q$, and $m_1 = m_2 = m$, determine the ratio θ_1/θ_2. (*b*) Estimate the distance between the spheres.

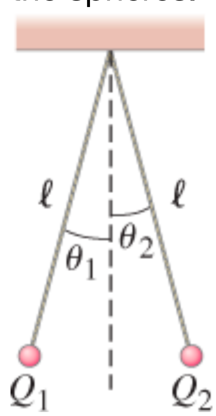

Figure 16–64

Problem 52.

53. A positive point charge $Q_1 = 2.5 \times 10^{-5}$ C is fixed at the origin of coordinates, and a negative point charge $Q_2 = -5.0$

× 10^{-6} C is fixed to the x axis at x = +2.4 m. Find the location of the place(s) along the x axis where the electric field due to these two charges is zero.

54. Dry air will break down and generate a spark if the electric field exceeds about 3×10^6 N/C. How much charge could be packed onto a green pea (diameter 0.75 cm) before the pea spontaneously discharges? [*Hint:* **Eqs. 16–4** work outside a sphere if r is measured from its center.]
55. Two point charges, $Q_1 = -6.7$ μC and $Q_2 = 1.8$ μC, are located between two oppositely charged parallel plates, as shown in **Fig. 16–65**. The two charges are separated by a distance of $x = 0.47$ m. Assume that the electric field produced by the charged plates is uniform and equal to E = 53,000 N/C. Calculate the net electrostatic force on Q_1 and give its direction.

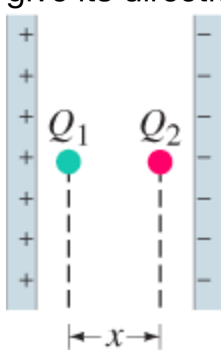

Figure 16–65
Problem 55.

56. Packing material made of pieces of foamed polystyrene can easily become charged and stick to each other. Given that the density of this material is about 35 kg/m^3, estimate how much charge might be on a 2.0-cm-diameter foamed polystyrene sphere, assuming the electric force between two spheres stuck together is equal to the weight of one sphere.
57. A point charge (m = 1.0 gram) at the end of an insulating

cord of length 55 cm is observed to be in equilibrium in a uniform horizontal electric field of 9500 N/C, when the pendulum's position is as shown in **Fig. 16–66**, with the charge 12 cm above the lowest (vertical) position. If the field points to the right in **Fig. 16–66**, determine the magnitude and sign of the point charge.

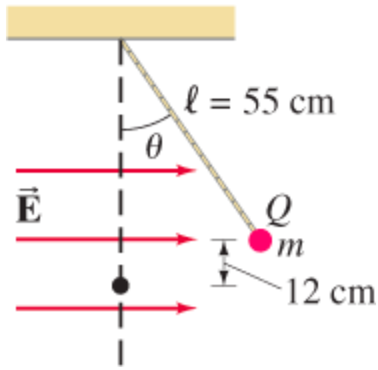

Figure 16–66

Problem 57.

58. Two small, identical conducting spheres A and B are a distance *R* apart; each carries the same charge *Q*. (*a*) What is the force sphere B exerts on sphere A? (*b*) An identical sphere with zero charge, sphere C, makes contact with sphere B and is then moved very far away. What is the net force now acting on sphere A? (*c*) Sphere C is brought back and now makes contact with sphere A and is then moved far away. What is the force on sphere A in this third case?
59. For an experiment, a colleague of yours says he smeared toner particles uniformly over the surface of a sphere 1.0 m in diameter and then measured an electric field of 5000 N/C near its surface. (*a*) How many toner particles (**Example 16–6**) would have to be on the surface to produce these results? (*b*) What is the total mass of the toner particles?
60. A proton ($m = 1.67 \times 10^{-27}$ kg) is suspended at rest in a

uniform electric field $\overrightarrow{E}$. Take into account gravity at the

Earth's surface, and determine $\overrightarrow{E}$.

61.

For 1, 3, & 4 use

$$F = (9\times 10^9)\frac{(q_1)(q_2)}{d^2}$$

1) $F = (9\times 10^9)\dfrac{(26\times 1.6\times 10^{-19})(-1.6\times 10^{-19})}{(1.5\times 10^{-12})^2}$

$= -\dfrac{9\times 26\times 1.6^2}{1.5^2}\times 10^{-5}$

$= -3\times 10^{-3}\text{N}$

The negative sign signifies attraction.

3) $F = (9\times 10^9)\dfrac{(25\times 10^{-6})(2.5\times 10^{-3})}{0.16^2}$

$= \dfrac{9\times 25\times 2.5}{0.16^2}\times 10^0$

$= 2.2\times 10^4\text{N}$

The positive sign signifies repulsion.

4) $F = (9\times 10^9)\dfrac{(1.6\times 10^{-19})(1.6\times 10^{-19})}{(4\times 10^{-15})^2}$

$= \dfrac{9\times 1.6^2}{4^2}\times 10$

$= 14.4\text{N}$

The positive sign signifies repulsion.

2) $\dfrac{-48\times 10^{-6}}{-1.6\times 10^{-19}} = 3\times 10^{14}$ electrons.

7) $k\dfrac{q_1q_2}{d_2^2}=3k\dfrac{q_1q_2}{d_1^2} \Rightarrow \dfrac{1}{d_2^2}=\dfrac{3}{d_1^2} \Rightarrow d_1^2=3d_2^2 \Rightarrow d_1=\sqrt{3}d_2.$

If $d_1 = 6.52\,\text{cm}$, $d_2 = 6.52/\sqrt{3} = 3.76\,\text{cm}$.

8) $\dfrac{-28\times 10^{-6}}{-1.6\times 10^{-19}} = 1.75\times 10^{14}$ electrons.

$m = (1.75\times 10^{14})(9.1\times 10^{-31}) = 1.6\times 10^{-16}\,\text{kg}.$

10) $|F_E| = 9\times 10^9\dfrac{(1.6\times 10^{-19})^2}{(0.53\times 10^{-10})^2} = 8.2\times 10^{-8}\,\text{N}.$

$|F_G| = 6.67\times 10^{-11}\dfrac{(9.1\times 10^{-31})(1.7\times 10^{-27})}{(0.53\times 10^{-10})^2}$

$= 3.7\times 10^{-47}\,\text{N}.$

Ratio: $\left|\dfrac{F_E}{F_G}\right| = 2.2\times 10^{39}$

19) $F = (-1.6\times 10^{-19})(2460) = -3.9\times 10^{-16}\,\text{N}.$
The negative means the force points west.

20) $E = \dfrac{F_E}{|e|} = \dfrac{1.86\times 10^{-14}}{1.6\times 10^{-19}} = 1.2\times 10^5\,\text{N/C south}.$

21) $E = 9\times 10^9\dfrac{33\times 10^{-6}}{(0.217)^2} = 6.3\times 10^6\,\text{N/C upward}.$

22) Take "down" as negative.

$E = \dfrac{-6.4}{-7.3\times 10^{-6}} = 8.8\times 10^5\,\text{N/C (up)}.$

23) $F = eE = (-1.6\times 10^{-19})(756) = -1.2\times 10^{-16}\,\text{N}.$

$a = \dfrac{F}{m} = \dfrac{-1.2\times 10^{-16}}{9.1\times 10^{-31}} = -1.3\times 10^{14}\,\text{m/s}^2.$

The negatives mean the acceleration (and force) are in the opposite direction as the field.

24) Say the neg. charge is at the origin and the pos. charge at $x = +6.0\,\text{cm}$. Then

$E = k\dfrac{-8\times 10^{-6}}{(0.03)^2} - k\dfrac{5.8\times 10^{-6}}{(0.03)^2}$

$= \dfrac{9\times 10^9}{(0.03)^2}(-8-5.8)10^{-6} = -1.4\times 10^8\,\text{N/C}.$

The negative means it points toward the origin.