Chapter 19 Solutions - Problems 3, 4, 5, 9, 11, 12, 14, 17, 19, 23, 27, 28, 31, 32, 37, 40, 42, 48, 49

3. This is a chemistry problem. It rests on knowing that 6.023 x 10^{26} atoms are in a kmole, and a kmole of Cu is 63.5 kg by definition (the same number in kg as the atomic weight of Cu). Therefore, 0.002 kg of Cu is equivalent to only (0.002)/(65.5) of a kmole.
   a. # atoms = (0.002/65.5)kmole x 6.023 x 10^{26} atoms/kmole = 1.9 x 10^{22} atoms.
   b. # electrons = 1.9 x 10^{22} atoms x 29 electrons/atom = 5.5 x 10^{23} electrons.

4. The purpose of this problem is to impress upon you how very small is the percentage of electrons that participate typically when an object is charged. Knowing that the charge on a single electron is 1.6 x 10^{-19} C, the charge 4.0 x 10^{-7} C is quickly found to be 2.5 x 10^{12} electrons. This is a tiny fraction of the total number calculated in b) above! % removed = (2.5 x 10^{12}/5.5 x 10^{22}) x 100 = 4.6 x 10^{-10} %.

5. From Newton's 2nd law, the force on each charge is equal in magnitude and opposite in direction. The difference in sign between the charges tells they attract each other. For problems like this, sketch a picture, locate the two charges on the x-axis and draw the direction of the force on each charge. Then use Coulomb's law to find the magnitude of the force. Do not use + or - signs in the coulomb formula. The vector nature of the forces is taken care of by your picture! You should find from Coulomb's law that the magnitude of the force is 3.5 N. From your sketch, the force on the +5.0 microC charge at x = 0 is to the right, and the force on the –7.0 microC charge at x = 0.30 m is to the left.

9. Finding the force in part a) is easy. Just use the Coulomb law to get 4.3 x 10^{-5} N. Part b) is less obvious. Remember that the two spheres are identical and are conductors. This means that when they are brought together to touch each other, the act as one conductor. As a result, the total charge redistributes itself, with an equal amount on each sphere. The total charge is (+0.30 – 0.40) microC = –0.10 microC. Each sphere, when separated, must have –0.05 microC. Substituting into Coulomb's law gives 9.0 x 10^{-7} N.

11. In part a) you need to do very little actual computation since you can use a ratio. Remember that Coulomb's law is an inverse square law, where F is proportional to $1/r^2$. Since the separation distance changes from 4.0 m to 3.0 m, the new force is

$$F(\text{at 3.0 m}) = (4.0^2/3.0^2) \times F(\text{at 4.0 m}) = (16/9) \times 250 \times 10^{-10}\ \text{N} = 4.4 \times 10^{-8}\ \text{N}.$$

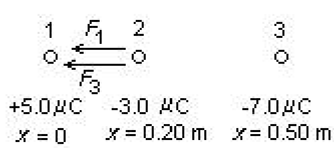
For part b), we know that $q_2 = 7q_1$. We also know that the force is 2.50 x 10^{-8} N. Substituting into Coulomb's law, we get

$$2.5 \times 10^{-8}\ \text{N} = (k)(q_1)(7q_1)/(4.0\ \text{m})^2 = (7/16)kq_1^2.$$

Solving for q_1 (and using $k = 9.0 \times 10^9\ \text{Nm}^2/\text{C}^2$) gives

$$q_1 = 2.5 \times 10^{-9}\ \text{C and } q_2 = 1.8 \times 10^{-8}\ \text{C}.$$

12. The three charges are sketched, with the forces acting on the –3.0 microC charge. The force exerted by charge 1 on charge 2 is labeled F_1, and the force exerted by charge 3 is F_3. The direction of each force is determined by the signs of the charges involved. The net force on charge 2 is the vector sum of the two forces. Since each force is to the left, and since the two forces are parallel, the two magnitudes can simply be added. As in problem 5 we do not use signs in the calculation of the two Coulomb's law forces because the vector notions have already been accounted for by the diagram. Substituting into Coulomb's law gives
   F_1 = 3.4 N and F_3 = 2.1 N. Thus F_{total} = 5.5 N, all to the left.



14. This problem requires care! As usual you should draw the two charges in their proper locations. The charge at x = 0 has the value +5.0 microC, and the charge at x = 4.0 m has the value –3.0 microC. Now call the region to the left of x = 0 region I. Call the region between x = 0 and x = 4.0 m region II. Finally, call the region the the right of x = 4.0 m as region III. The only place where a third charge can be placed such that the two contributing forces on this third charge can be opposite one another is in region III. Be sure you understand why this is so by checking what happens if the third charge is in region I or II. You will find the two forces are in the same direction and therefore can never cancel.

Now that you are confident the third charge is in region III, you are ready to write the condition the two opposing forces have the same magnitudes. Let the third charge be located at the unknown position x and be labeled q. The distance from q to the charge at x = 0 is just $r = x$, but the distance from q to the charge at x = 4.0 is $r = x$ –4.0. Thus, we equate the two Coulomb forces.

$$\frac{(5.0)q}{x^2} = \frac{(3.0)q}{(x-4.0)^2}$$

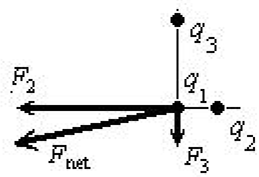
Notice that the charge q drops out of the equation. The equation is easy to evaluate by taking the square root of both sides and solving for x. (We don't have to worry about signs in taking the root because we know that x is larger than 4.0). The result is $x = 17.8$ m.

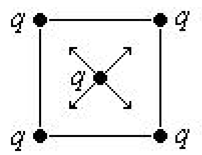
17. The three equal 4.0 microC charges are located as shown in the left-hand figure below. The net force F on charge q_1 is the vector sum of the individual forces, F_2 and F_3 exerted by the other two charges, q_2 and q_3. This problem is relatively easy because the forces F_2 and F_3 are already in component form. Thus, the resultant net force F can be calculated from the Pythagorean theorem once F_2 and F_3 have been found. First, we compute F_3. For compactness, I have eliminated units from the computations.

$$F_3 = (9.0 \times 10^9) \frac{(4.0) \times 10^{-12}}{3.0^2} = 0.016 \text{ N}$$

The force F_2 is 4 times as large as F_3, since the charge q_2 is the same as q_3 but the distance is half. Thus $F_2 = 0.064$ N. The Pythagorean theorem gives us $F = 0.066$ N.

Next, we find the angle relative to a reference axis. Looking at the figure, the net force is seen to be in the third quadrant. The angle is $\tan^{-1}(F_3/F_2)$, which gives 14 degrees below the negative x-axis.





19. Refer to the figure above right. This is a very simple problem because of the symmetry. Each force is opposed by an equal and opposite force. Therefore, the net force must be zero.

23. The electric field **E** is a vector defined in terms of the force on a positive test charge. The magnitude of the field is $E = F/q$, and the direction of the field is the same as the direction of the force. For this problem, the electric field has the strength 3000 N/C, and its direction is along the $+x$ axis. The force on each charge is therefore determined from the definition of **E**, (as a vector)

    a. If $q = +5.0$ microC, then F_x = (5.0 microC) x (3000 N/C) = +0.015 N.
    b. If $q = -5.0$ microC, then F_x = (–5.0 microC) x (3000 N/C) = –0.015 N.

27. It may interest you to know that if an electrically isolated conducting sphere of radius R has on it a total charge Q, and is located away from other charges, the charges on the sphere will distribute themselves uniformly around the surface of the sphere. It will then act exactly as a point charge Q located at the center of the sphere, provided $r > R$. The only problem is if a charge q is placed near the conducting sphere, there will be polarization effects to worry about. However, if the charge q, is far enough away so that r is much greater than R, then there is no worry, and one can regard the relatively small sphere as a point charge. Now we can answer the question as if the small sphere is in fact a point charge.

    a. Since an **E** field points away from a positive charge and towards a negative charge, the sphere must be negative.
    b. A charge of +1.0 C would experience a force of magnitude qE toward the sphere
    F = (1.0 C) x (3500 N/C) = 3500 N (toward the sphere).
    c. The charge Q on the sphere satisfies the relationship $E = kQ/r^2$. Substituting values, with a minus sign put in to take care of the direction of the field,
    $Q = -(3500 \text{ N/C}) \times (0.70 \text{ m})^2 / (9.0 \times 10^9 \text{ Nm}^2/\text{C}^2) = -1.9 \times 10^{-7}$ C.

28. Place everything on the y axis. The electric field has only the component E_y = -600 N/C and exerts a force $F_E = qE_y$ on the charge. The tension of the thread exerts an upward force $+T$ on the ball. The gravity force is $F_g = -mg$ = -(0.003 kg)x(9.8 m/s^2) = –0.029 N. The solution then, is based on balancing all the vertical forces acting on the ball.

    a. Assume the charge on the ball is +9.0 microC. The electrical force is
    $F_E = qE_y = (9.0 \times 10^{-6}$ C) x(-600 N/C) = -0.0054 N, and+
    T – 0.0294 N – 0.0054 N = 0, or $T = 0.035$ N.

    b. Assume the charge on the ball is –9.0 microC. The electrical force is now upward, so that
    +T – 0.0294 N + 0.0054 N = 0, or T = 0.024 N.

31. This problem is similar to problem 19-14. which we have already solved. Using the logic I explained in class, the only place where the field can be zero (since the two charges have like signs) is on the x axis between the two charges. Each charge contributes to the field along the x axis. Between the two charges, the two contributions to E_x will oppose each other, and I thus will set the magnitudes of the two field equal to each other at an unknown point x in order to have a zero field at that point.

$$k\frac{|q_1|}{d_1^2} = k\frac{|q_2|}{d_2^2} \Rightarrow \frac{2.0}{x^2} = \frac{3.0}{(0.5-x)^2}$$

Taking the square root of both sides and solving for x yields $x = 0.225$ m.

32. I hope you spot the fact that the answer must be identical to the answer to problem 31!

37. The definition of the volt is "voltage difference V_{ab} between points a and b = the work done per coulomb of positive charge moved from a to b."

   a. As a result, in this problem, since 10 J of work was done to move the +1.0 C charge from A to B, the voltage difference must be 10 volts. Point B is 10 volts higher in potential than point A.
   b. The charge on a proton is 1.6×10^{-19} C. Therefore, the work done in moving a proton through a 10-volt potential difference is $(1.6 \times 10^{-19}\text{ C}) \times (10\text{ V}) = 1.6 \times 10^{-18}$ J.

40. This problem is an example involving energy conservation. The loss in electrical potential energy is converted into a gain in an equal amount of kinetic energy. You may recall that "the change in PE + the change in KE = 0." This translates to the expression

$$(PE_f - PE_i) + (KE_f - KE_i) = 0.$$

If this is something you have forgotten, relearn it! The change in PE is the product $q\Delta V$.

$$\Delta PE + \Delta KE = 0 \Rightarrow (1.6\times10^{-19}\text{ C})\times(-500\text{ J/C}) + \Delta KE = 0$$

Solving, we find the change in KE = $+8.0 \times 10^{-17}$ J.

42. As in the previous problem, we use energy conservation. In the expression $(PE_f - PE_i) + (KE_f - KE_i) = 0$, the PE increases and the KE decreases. You can assume $PE_i = 0$, and $KE_f = 0$. Notice the signs of each term as it is used in the energy equation. The term $(PE_f - PE_i)$ is $(qV - 0)$. Thus,

$$(-1.60 \times 10^{-19}\text{ C}) \times (-35\text{ V}) - 0 + (0 - KE_i) = 0.$$
$$5.6 \times 10^{-18}\text{ J} - KE_i = 0, \text{ or } KE_i = 5.6 \times 10^{-18}\text{ J.}$$

48. Once again, we use energy conservation. You can fill in the unknowns just as was done in problems 40 and 42. You can also just think through the situation. For example, you know that the particle gains KE because it "falls" through a potential difference. The loss in potential energy has the magnitude qV and you know it must be negative. As a result, the particle gains an equal amount of KE. The two must be equal. Thus, $(1/2)mv^2 = q\Delta V$.

$$(1/2)(4)1.67 \times 10^{-27}\text{ kg})v^2 = 2(1.6 \times 10^{-19}\text{ C})(1.8 \times 10^6\text{ V})$$
$$v = 1.3 \times 10^7\text{ m/s.}$$

Of course, you can also just plug into the energy equation and let the answer appear automatically.

Let $PE_i = 2(1.6 \times 10^{-19}\text{ C})(1.8 \times 10^6\text{ V})$, and $PE_f = 0$.

Let $KE_i = 0$, and $KE_f = (1/2)mv^2$.

Plugging into $(PE_f - PE_i) + (KE_f - KE_i) = 0$ gives the same result.

49. Yup, here we go again with energy conservation! We can think physically or you can formally substitute into the energy conservation equation. You know that the magnitude of the drop in KE must equal the magnitude of the change in PE. For kicks, I'll substitute. Remember that the positive terminal is at the higher voltage, so that means you should get $V_f - V_i$ to be a negative number. In addition, for an electron, $q = -e = -1.6 \times 10^{-19}$ C

$$(PE_f - PE_i) + (KE_f - KE_i) = 0$$

$$-eV_f + eV_i + (1/2)m_e(v_f^2 - v_i^2) = 0$$

Solving for $(V_f - V_i)$, we find

$$V_f - V_i = \frac{1}{2}\frac{(9.1\times10^{-31}\text{ kg})}{(1.6\times10^{-19}\text{ C})}(2.25-6.25)\times10^{12} = -11.3\text{ V}$$