any) there is in the net electric force on the left ball and on the net electric force on the right ball. Show relevant force vectors. Also show the charge distribution on the metal ball. Explain briefly but completely.

Q21 You take two invisible tapes of some unknown brand, stick them together, and discharge the pair before pulling them apart and hanging them from the edge of your desk. When you bring an uncharged plastic pen within 10 cm of either the U tape or the L tape you see a slight attraction. Next you rub the pen through your hair, which is known to charge the pen negatively. Now you find that if you bring the charged pen within 8 cm of the L tape you see a slight repulsion, and if you bring the pen within 12 cm of the U tape you see a slight attraction. Briefly explain all of your observations.

Q22 You have three metal blocks marked A, B, and C, sitting on insulating stands. Block A is charged +, but blocks B and C are neutral (Figure 14.76).

Figure 14.76

Without using any additional equipment and without altering the amount of charge on block A, explain how you could make block B be charged + and block C be charged −. Explain your procedure in detail, including diagrams of the charge distributions at each step in the process.

Q23 You have two identical neutral metal spheres labeled A and B, mounted on insulating posts, and you have a plastic pen that charges negatively when you rub it on your hair (Figure 14.77).

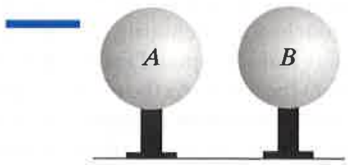

Figure 14.77

(a) (+ and −) Explain in detail, including diagrams, what operations you would carry out to give sphere A some positive charge and sphere B an equal amount of negative charge.
(b) (+ and +) Explain in detail, including diagrams, what operations you would carry out on the neutral spheres to give sphere A some positive charge and sphere B an equal amount of positive charge (the spheres are initially uncharged).

Q24 Here is a variant of "charging by induction." Place two uncharged metal objects so as to touch each other, one behind the other. Call them *front* object and *back* object. While you hold a charged comb in front of the *front* object, your partner moves away the *back* object (handling it through an insulator so as not to discharge it). Now you move the comb away. Explain this process. Use only labeled diagrams in your explanation (no prose!).

Q25 Metal sphere A is charged negatively and then brought near an uncharged metal sphere B (Figure 14.78). Both spheres rest on insulating supports, and the humidity is very low.

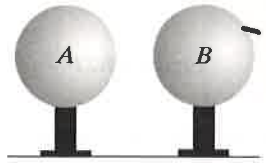

Figure 14.78

(a) Use +'s and −'s to show the approximate distribution of charges on the two spheres. (*Hint:* Think hard about *both* spheres, not just B.)

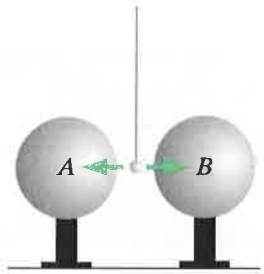

Figure 14.79

(b) A small, lightweight hollow metal ball, initially uncharged, is suspended from a string and hung between the two spheres (Figure 14.79). It is observed that the ball swings rapidly back and forth hitting one sphere and then the other. This goes on for 5 seconds, but then the ball stops swinging and hangs between the two spheres. Explain in detail, step by step, why the ball swings back and forth and why it finally stops swinging. Your explanation must include good physics diagrams.

Q26 Suppose that you try to measure the electric field $\vec{E}$ at a location by placing a charge Q_1 there and observing the force $\vec{F}_1$, so that you measure $E_1 = F_1/Q_1 = 1000$ N/C. Then you remove Q_1 and place a much larger charge $Q_2 = 30Q_1$ at the same location, and observe the force $\vec{F}_2$. This time you measure $E_2 = F_2/Q_2 = 1100$ N/C, though you expected to measure 1000 N/C again. What's going on here? Why didn't you get $E = 1000$ N/C in your second measurement? Sketch a possible situation that would lead to these measurements.

PROBLEMS

Section 14.1

•P27 You rub a plastic comb through your hair and it now carries a charge of -4×10^{-10} C. What is the charge on your hair?

•P28 Many heavy nuclei are "alpha emitters": they emit an alpha particle, which is the historical name for the nucleus of a helium atom, which contains two protons. For example, a thorium nucleus containing 90 protons is an alpha-emitter. What element does thorium turn into as a result of emitting an alpha particle?

Section 14.2

•P29 Which of the following could be reasonable explanations for how a piece of invisible tape gets charged? Select all that apply. (1) Protons are pulled out of nuclei in one tape and transferred to another tape. (2) Charged molecular fragments are broken off one tape and transferred to another. (3) Electrons are pulled out of molecules in one tape and transferred to another tape. (4) Neutrons are pulled out of nuclei in one tape and transferred to another tape.

•P30 You rub a clear plastic pen with wool, and observe that a strip of invisible tape is attracted to the pen. Assuming that the pen has a net negative charge, which of the following could be true? Select all that apply. (1) The tape might be negatively charged. (2) The tape might be positively charged. (3) The tape might be uncharged. (4) There is not enough information to conclude anything.

•P31 Which observation provides evidence that two objects have the same sign charge? (a) The two objects repel each other. (b) The two objects attract each other. (c) The two objects do not interact at all. (d) The strength of the interaction between the two objects depends on distance.

Section 14.3

•P32 Which statements about a neutral atom are correct? Select all that apply. (1) A neutral atom is composed of both positively and negatively charged particles. (2) The positively charged particles in the nucleus are positrons. (3) The electrons are attracted to the positively charged nucleus. (4) Positively charged protons are located in the tiny, massive nucleus. (5) The radius of the electron cloud is twice as large as the radius of the nucleus. (6) The negatively charged electrons are spread out in a "cloud" around the nucleus.

•P33 If the distance between a neutral atom and a point charge is tripled, by what factor does the force on the atom by the point charge change? Express your answer as a ratio: new force/original force.

•P34 There is a region where an electric field points to the right, due to charged particles somewhere. A neutral carbon atom is placed inside this region. Draw a diagram of the situation, and use it to answer the following question: Which of the following statements are correct? Select all that apply. (1) Because the net charge of the carbon atom is zero, it cannot be affected by an electric field. (2) The electron cloud in the carbon atom shifts to the left. (3) The neutral carbon atom polarizes and becomes a dipole. (4) The nucleus of the carbon atom shifts to the left.

•P35 A charged particle with charge q_1 is a distance r from a neutral atom, as shown in Figure 14.80.

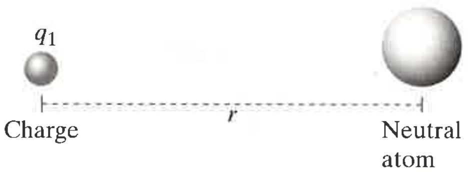

Figure 14.80

(1) If q_1 is negative, which diagram (1–10) in Figure 14.81 best shows the charge distribution in the neutral atom in this situation?

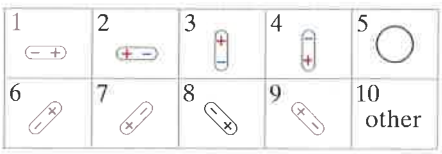

Figure 14.81

(2) Which of the arrows (*a–j*) in Figure 14.82 best indicates the direction of the electric field at the location of the charged particle, made by the polarized neutral atom?

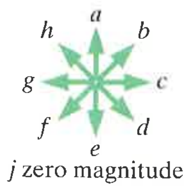

Figure 14.82

(3) Which of the arrows (*a–j*) in Figure 14.82 best indicates the direction of the force on the charged particle, due to the polarized neutral atom? **(4)** Which of the arrows (*a–j*) in Figure 14.82 best indicates the direction of the force on the polarized neutral atom, due to the charged particle?

•P36 A charged piece of invisible tape is brought near your hand, as shown in Figure 14.83. Your hand is initially neutral.

Figure 14.83

(a) If the tape is negatively charged, which of the diagrams 1–10 in Figure 14.81 best shows the polarization of a neutral molecule in your hand? **(b)** Which arrow in Figure 14.82 best indicates the direction (*a–j*) of the electric field at the location of the tape due to the large number of polarized molecules in your hand? **(c)** Which arrow in Figure 14.82 best indicates the direction (*a–j*) of the force on the tape due to the polarized molecules in your hand? **(d)** Which arrow in Figure 14.82 best indicates the direction (*a–j*) of the force on your hand due to the charged tape?

••P37 An electron and a neutral carbon atom are initially 1×10^{-6} m apart (about 10 000 atomic diameters), and there are no other particles in the vicinity. The polarizability of a carbon atom has been measured to be $\alpha = 1.96 \times 10^{-40}\ \text{C} \cdot \text{m}/(\text{N/C})$. **(a)** Calculate the initial magnitude and direction of the acceleration of the electron. Explain your steps clearly. Pay particular attention to clearly defining your algebraic symbols. Don't put numbers into your calculation until the very end. **(b)** If the electron and carbon atom were initially twice as far apart, how much smaller would the initial acceleration of the electron be?

••P38 In Problem P37, replace "electron" with "water molecule" and repeat the analysis. A water molecule has a permanent dipole moment whose magnitude is $6.2 \times 10^{-30}\ \text{C} \cdot \text{m}$, which is much larger than the induced dipole for this situation. Assume that the dipole moment of the water molecule points toward the carbon atom.

•••P39 In Figure 14.84 there is a permanent dipole on the left with dipole moment $\mu_1 = Qs_1$ and a neutral atom on the right with polarizability α, so that it becomes an induced dipole with dipole moment $\mu_2 = qs_2 = \alpha E_1$, where E_1 is the magnitude of the electric field produced by the permanent dipole. Show that the force the permanent dipole exerts on the neutral atom is

$$F \approx \left(\frac{1}{4\pi\varepsilon_0}\right)^2 \frac{12\alpha\mu_1^2}{r^7}$$

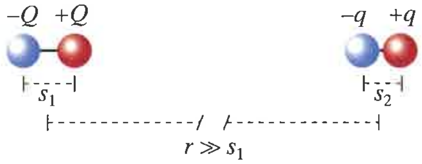

Figure 14.84

Hint: It is convenient to use the "binomial expansion" that you may have learned in calculus, that $(1+\epsilon)^n \approx 1+n\epsilon$ is $\epsilon \ll 1$. Note that n can be negative.

•••P40 Try rubbing a plastic pen through your hair, and you'll find that you can pick up a tiny scrap of paper when the pen is about one centimeter above the paper. From this simple experiment you can estimate how much an atom in the paper is polarized by the pen! You will need to make several assumptions and approximations. Hints may be found at the end of the chapter. **(a)** Suppose that the center of the outer electron cloud ($q = -4e$) of a carbon atom shifts a distance s when the atom is polarized by the pen. Calculate s algebraically in terms of the charge Q on the pen. **(b)** Assume that the pen carries about as much charge Q as we typically find on a piece of charged invisible tape. Evaluate s numerically. How does this compare with the size of an atom or a nucleus? **(c)** Calculate the polarizability α of a carbon atom. Compare your answer to the measured value of 1.96×10^{-40} C· m/(N/C) (T. M. Miller and B. Bederson, "Atomic and molecular polarizabilities: a review of recent advances," *Advances in Atomic and Molecular Physics*, 13, 1–55, 1977). **(d)** Carefully list all assumptions and approximations you made.

Section 14.4

•P41 A solid plastic ball has negative charge uniformly spread over its surface. Which of the diagrams in Figure 14.85 best shows the polarization of molecules inside the ball?

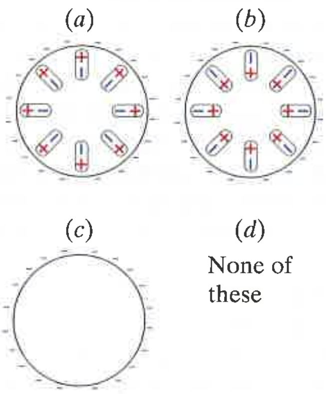

Figure 14.85

•P42 A dipole consisting of two oppositely charged balls connected by a wooden stick is located as shown in Figure 14.86. A block of plastic is located nearby, as shown. Locations B, C, and D all lie on a line perpendicular to the axis of the dipole, passing through the midpoint of the dipole.

Before selecting answers to the following questions, draw your own diagram of this situation, showing all the fields and charge distributions requested.

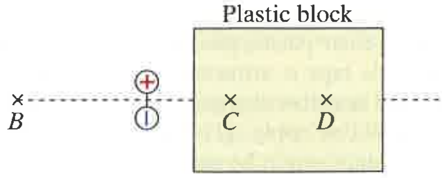

Figure 14.86

Answer the following questions by selecting either a direction (*a–j*) from Figure 14.82 or an orientation of a polarized molecule (1–10) from the diagrams in Figure 14.81.

(a) Which of the arrows (*a–j*) best indicates the direction of the electric field at location C due only to the dipole? **(b)** Which of the arrows (*a–j*) best indicates the direction of the electric field at location D due only to the dipole? **(c)** Which of the diagrams (1–10) best indicates the polarization of a molecule of plastic at location C? **(d)** Which of the diagrams (1–10) best indicates the polarization of a molecule of plastic at location D? **(e)** Which of the following statements is correct? (1) A molecule located at C would not be polarized at all. (2) The polarization of a molecule located at D would be the same as the polarization of a molecule located at C. (3) A molecule located at D would be polarized more than a molecule located at C. (4) A molecule located at D would be polarized less than a molecule located at C. **(f)** Which of the arrows (*a–j*) best indicates the direction of the electric field at location B due only to the dipole? **(g)** Which of the arrows (*a–j*) best indicates the direction of the electric field at location B due only to the plastic block? The magnitude of the electric field at B due to the plastic is less than the magnitude of the electric field at B due to the dipole. **(h)** Which of the arrows (*a–j*) best indicates the direction of the net electric field at location B? **(i)** Which of the following statements is correct? (1) The electric field at B due only to the dipole would be larger if the plastic block were not there. (2) The electric field at B due only to the dipole would be the same if the plastic block were not there. (3) The electric field at B due only to the dipole would be smaller if the plastic block were not there. (4) The electric field at B due only to the dipole would be zero if the plastic block were not there.

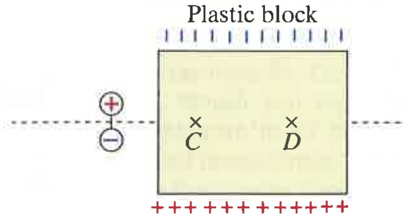

Figure 14.87

(j) Using the diagrammatic conventions discussed in the text, a student drew the diagram in Figure 14.87 to help answer the questions asked above. Which of the following statements about the student's diagram are true? Check all that apply. (1) The direction of polarization of the plastic block is wrong. (2) The diagram is correct; this is just a different way of drawing the polarization. (3) The diagram shows mobile charges; this is wrong because an insulator does not have mobile charged particles.

Section 14.5

•**P43** The mobility of Na^+ ions in water is 5.2×10^{-8} (m/s)/(N/C). If an electric field of 2400 N/C is maintained in the fluid, what is the drift speed of the sodium ions?

•**P44** An electric field is applied to a solution containing bromide ions. As a result, the ions move through the solution with an average drift speed of 3.7×10^{-7} m/s. The mobility of bromide ions in solution is 8.1×10^{-8} (m/s)/(N/C). What is the magnitude of the net electric field inside the solution?

Section 14.6

•**P45** Which of the following are true? Check all that apply. (1) If the net electric field at a particular location inside a piece of metal is zero, the metal is not in equilibrium. (2) The net electric field inside a block of metal is zero under all circumstances. (3) The net electric field at any location inside a block of copper is zero if the copper block is in equilibrium. (4) The electric field from an external charge cannot penetrate to the center of a block of iron. (5) In equilibrium, there is a net flow of mobile charged particles inside a conductor.

•**P46** Which of the following are true? Select all that apply. (1) In equilibrium, there is no net flow of mobile charged particles inside a conductor. (2) The electric field from an external charge cannot penetrate to the center of a block of iron. (3) The net electric field inside a block of aluminum is zero under all circumstances. (4) If the net electric field at a particular location inside a piece of metal is not zero, the metal is not in equilibrium. (5) The net electric field at any location inside a block of copper is zero if the copper block is in equilibrium.

•**P47** A negatively charged iron block is placed in a region where there is an electric field downward (in the $-y$ direction) due to charges not shown. Which of the diagrams (a–f) in Figure 14.88 best describes the charge distribution in and/or on the iron block?

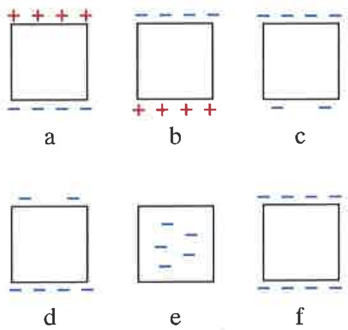

Figure 14.88

•**P48** Two small, negatively charged plastic spheres are placed near a neutral iron block, as shown in Figure 14.89. Which arrow (*a–j*) in Figure 14.89 best indicates the direction of the net electric field at location *A*?

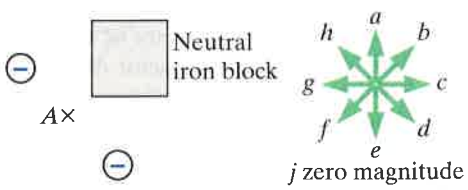

Figure 14.89

•**P49** A neutral copper block is polarized as shown in Figure 14.90, due to an electric field made by external charges (not shown). Which arrow (*a–j*) in Figure 14.90 best indicates the direction of the net electric field at location *B*, which is inside the copper block?

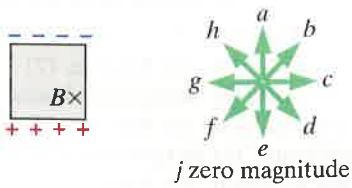

Figure 14.90

•**P50** **(a)** Which of the diagrams (A–F) in Figure 14.91 correctly displays the polarization of a *metal* sphere by an electric field that points to the left, using the conventions discussed in this chapter? **(b)** Which of the diagrams (A–F) in Figure 14.91 correctly displays the polarization of a *plastic* sphere by an electric field that points to the left, using the conventions discussed in this chapter?

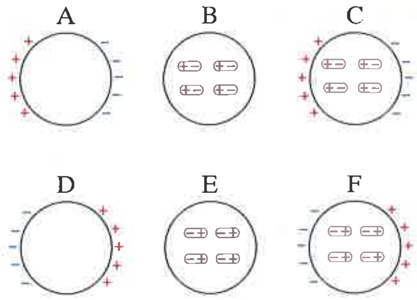

Figure 14.91

•**P51** You place a neutral block of nickel near a small glass sphere that has a charge of 2×10^{-8} C uniformly distributed over its surface, as shown in Figure 14.92.

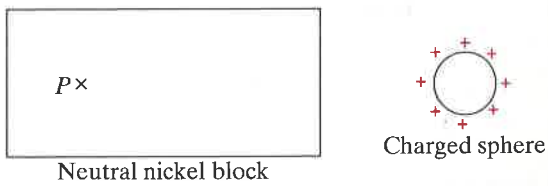

Figure 14.92

(a) About how long do you have to wait to make sure that the mobile electron sea inside the nickel block has reached equilibrium? (1) Less than a nanosecond (1×10^{-9} s), (2) Several hours, (3) About 1 s, (4) About 10 min **(b)** In equilibrium, what is the average drift speed of the mobile electrons inside the nickel block? (1) About 1×10^5 m/s, (2) About 1×10^{-5} m/s, (3) 0 m/s **(c)** In the equation $\bar{v} = uE$, what is the meaning of the symbol u? (1) The density of mobile electrons inside the metal, in electrons/m^3, (2) The mobility of an electron inside the metal, in (m/s)/(N/C), (3) The time it takes a block of metal to reach equilibrium, in seconds

•**P52** This question focuses on reasoning about equilibrium inside the nickel block shown in Figure 14.92. Start with these premises:

- The definition of equilibrium inside a conductor and
- The relationship between average drift speed and electric field in a conductor

to reason about which situations are *possible* inside the nickel block at equilibrium. Some of the situations listed below are possible, some are ruled out by one premise, and some are ruled out by two premises. If a situation is ruled out by two premises, choose both.

Case 1: $\bar{v} = 0$ and $E_{\text{net}} = 0$ (1) Possible, (2) Not possible by definition of equilibrium, (3) Not possible because $\bar{v} = uE_{\text{net}}$
Case 2: $\bar{v} = 0$ and $E_{\text{net}} > 0$ (1) Possible, (2) Not possible by definition of equilibrium, (3) Not possible because $\bar{v} = uE_{\text{net}}$
Case 3: $\bar{v} > 0$ and $E_{\text{net}} = 0$ (1) Possible, (2) Not possible by definition of equilibrium, (3) Not possible because $\bar{v} = uE_{\text{net}}$
Case 4: $\bar{v} > 0$ and $E_{\text{net}} > 0$ (1) Possible, (2) Not possible by definition of equilibrium, (3) Not possible because $\bar{v} = uE_{\text{net}}$
Now that you have considered each case, in equilibrium, which one is the only situation that is physically possible? (1) Case 1, (2) Case 2, (3) Case 3, (4) Case 4

•P53 A positively charged sphere is placed near a neutral block of nickel, as shown in Figure 14.92. **(a)** Which of the diagrams in Figure 14.93 best represents the equilibrium distribution of charge on the neutral nickel block?

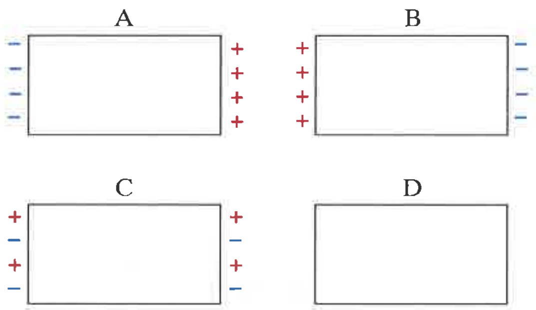

Figure 14.93

(b) At location P inside the nickel block the electric field due to the charged sphere is $\langle -625,0,0\rangle$ N/C. At equilibrium, which of the following statements must be true? (1) It is not possible to determine the electric field at location P due only to charges on the surface of the nickel block. (2) The electric field at location P due only to charges on the surface of the nickel block is $\langle 0,0,0\rangle$ N/C. (3) Because the net electric field at location P is $\langle 0,0,0\rangle$ N/C, the field at P due only to charges on the surface of the polarized nickel block must be $\langle 625,0,0\rangle$ N/C.

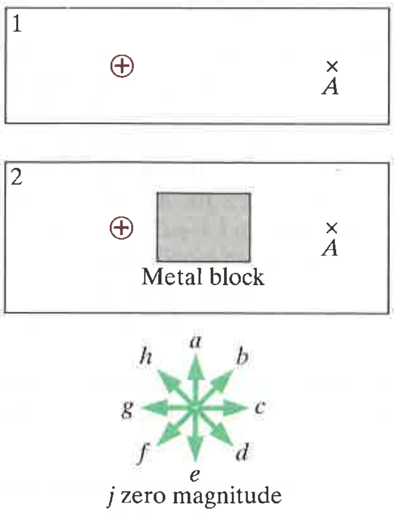

Figure 14.94

•P54 **(a)** The positively charged particle shown in diagram 1 in Figure 14.94 creates an electric field $\vec{E}_p$ at location A. Which of the arrows (a–j) in Figure 14.94 best indicates the direction of $\vec{E}_p$ at location A? **(b)** Now a block of metal is placed in the location shown in diagram 2 in Figure 14.94. Which of the arrows (a–j) in Figure 14.94 best indicates the direction of the electric field $\vec{E}_m$ at location A due only to the charges in and/or on the metal block? **(c)** $|\vec{E}_p|$ is greater than $|\vec{E}_m|$. With the metal block still in place, which of the arrows (a–j) in Figure 14.94 best indicates the direction of the net electric field at location A? **(d)** With the metal block still in place, which of the following statements about the magnitude of $\vec{E}_p$, the field due only to the charged particle, is correct? (1) $|\vec{E}_p|$ is less than it was originally, because the block is in the way. (2) $|\vec{E}_p|$ is the same as it was originally, without the block. (3) $|\vec{E}_p|$ is zero, because the electric field due to the particle can't go through the block. **(e)** With the metal block still in place, how does the magnitude of $\vec{E}_{\text{net}}$ at location A compare to the magnitude of $\vec{E}_p$? **(f)** Which of the arrows (a–j) in Figure 14.94 best indicates the direction of the net electric field at the center of the metal block (inside the metal)?

•P55 In a particular metal, the mobility of the mobile electrons is 0.0077 (m/s)/(N/C). At a particular moment the net electric field everywhere inside a cube of this metal is 0.053 N/C in the $+x$ direction. What is the average drift speed of the mobile electrons in the metal at this instant?

••P56 A neutral solid metal sphere of radius 0.1 m is at the origin, polarized by a point charge of 6×10^{-8} C at location $\langle -0.3,0,0\rangle$ m. At location $\langle 0,0.07,0\rangle$ m, what is the electric field contributed by the polarization charges on the surface of the metal sphere? How do you know?

••P57 A point charge of 3×10^{-9} C is located at the origin. **(a)** What is the magnitude of the electric field at location $\langle 0.2,0,0\rangle$ m? **(b)** Next, a short, straight, thin copper wire 3 mm long is placed along the x axis with its center at location $\langle 0.1,0,0\rangle$ m. What is the approximate change in the magnitude of the electric field at location $\langle 0.2,0,0\rangle$ m? **(c)** Does the magnitude of the electric field at location $\langle 0.2,0,0\rangle$ m increase or decrease as a result of placing the copper wire between this location and the point charge? **(d)** Does the copper metal block the electric field contributed by the point charge?

••P58 A metal ball with diameter of a half a centimeter and hanging from an insulating thread is charged up with 1×10^{10} excess electrons. An initially uncharged identical metal ball hanging from an insulating thread is brought in contact with the first ball, then moved away, and they hang so that the distance *between their centers* is 20 cm. **(a)** Calculate the electric force one ball exerts on the other, and state whether it is attractive or repulsive. If you have to make any simplifying assumptions, state them explicitly and justify them. **(b)** Now the balls are moved so that as they hang, the distance *between their centers* is only 5 cm. Naively one would expect the force that one ball exerts on the other to increase by a factor of $4^2 = 16$, but in real life the increase is a bit less than a factor of 16. Explain why, including a diagram. (Nothing but the distance between centers is changed—the charge on each ball is unchanged, and no other objects are around.)

••P59 A thin, hollow spherical plastic shell of radius R carries a uniformly distributed negative charge $-Q$. A slice through the plastic shell is shown in Figure 14.95.

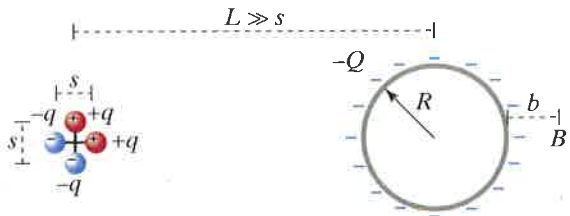

Figure 14.95

To the left of the spherical shell are four charges packed closely together as shown (the distance s is shown greatly enlarged for clarity). The distance from the center of the four charges to the center of the plastic shell is L, which is much larger than s ($L \gg s$). Remember that a uniformly charged sphere makes an electric field as though all the charge were concentrated at the center of the sphere. **(a)** Calculate the x and y components of the electric field at location B, a distance b to the right of the outer surface of the plastic shell. Explain briefly, including showing the electric field on a diagram. Your results should not contain any symbols other than the given quantities R, Q, q, s, L, and b (and fundamental constants). You need not simplify the final algebraic results except for taking into account the fact that $L \gg s$. **(b)** What simplifying assumption did you have to make in part (a)? **(c)** The plastic shell is removed and replaced by an uncharged metal ball, as in Figure 14.96.

At location A inside the metal ball, a distance b to the left of the outer surface of the ball, accurately draw and label the electric field $\vec{E}_{\text{ball}}$ due to the ball charges and the electric field $\vec{E}_4$ of the four charges. Explain briefly.

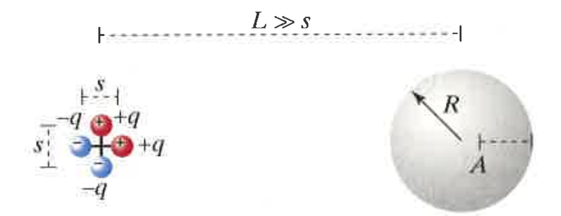

Figure 14.96

(d) Show the distribution of ball charges. **(e)** Calculate the x and y components of the net electric field at location A.

••P60 A very thin spherical plastic shell of radius 15 cm carries a uniformly distributed negative charge of −8 nC (-8×10^{-9} C) on its outer surface (so it makes an electric field as though all the charge were concentrated at the center of the sphere). An uncharged solid metal block is placed nearby. The block is 10 cm thick, and it is 10 cm away from the surface of the sphere. See Figure 14.97. **(a)** Sketch the approximate charge distribution of the neutral solid metal block.

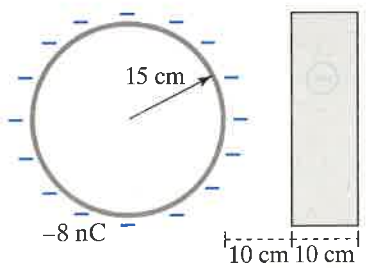

Figure 14.97

(b) Draw the electric field vector at the center of the metal block that is due solely to the charge distribution you sketched (that is, excluding the contributions of the sphere). **(c)** Calculate the magnitude of the electric field vector you drew. Explain briefly. If you must make any approximations, state what they are.

Section 14.7

•P61 You run your finger along the slick side of a positively charged tape, and then observe that the tape is no longer attracted to your hand. Which of the following are not plausible explanations for this observation? Check all that apply. (1) Sodium ions (Na^+) from the salt water on your skin move onto the tape, leaving the tape with a zero (or very small) net charge. (2) Electrons from the mobile electron sea in your hand move onto the tape, leaving the tape with a zero (or very small) net charge. (3) Chloride ions (Cl^-) from the salt water on your skin move onto the tape, leaving the tape with a zero (or very small) net charge. (4) Protons are pulled out of the nuclei of atoms in the tape and move onto your finger.

•P62 You observe that a negatively charged plastic pen repels a charged piece of invisible tape. You then observe that the same piece of tape is repelled when brought near a metal sphere. You are wearing rubber-soled shoes, and you touch the metal sphere with your hand. After you touch the metal sphere, you observe that the tape is attracted to the metal sphere. Which of the following statements could be true? Check all that apply. (1) Electrons from the sphere traveled through your body into the Earth. (2) Electrons from the sphere moved into the salt water on your skin, where they reacted with sodium ions. (3) After you touched it, the metal sphere was very nearly neutral. (4) Chloride ions from the salt water on your hand moved onto the sphere. (5) The excess negative charge from the sphere spread out all over your body. (6) Electrons from your hand moved onto the sphere. (7) Sodium ions from the salt water on your hand moved onto the sphere.

•P63 Blocks A and B are identical metal blocks. Initially block A is neutral, and block B has a net charge of 5 nC. Using insulating handles, the blocks are moved so they touch each other. After touching for a few seconds, the blocks are separated (again using insulating handles). **(a)** What is the final charge of block A? **(b)** What happened while the blocks were in contact with each other? (1) Protons moved from block B to block A. (2) Positrons moved from block B to block A. (3) Electrons moved from block A to block B. (4) Both protons and electrons moved. (5) No charged particles moved.

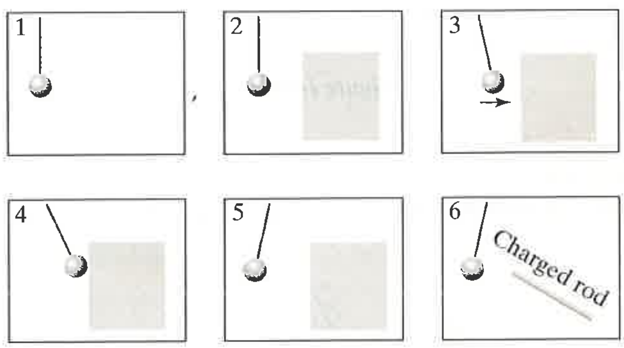

Figure 14.98

••P64 The diagrams in Figure 14.98 show a sequence of events involving a small lightweight aluminum ball that is suspended from a cotton thread. In order to get enough information, you will need to read through the entire sequence of events described below before beginning to answer the questions. Before trying to select answers, you will need to draw your own diagrams showing the charge state of each object in each situation. **(a)** A small, lightweight aluminum ball hangs from a cotton thread. You touch the ball briefly with your fingers, then release it (Diagram 1 in Figure 14.98). Which of the diagrams in Figure 14.99 best shows the distribution of charge in and/or on the ball at this moment, using the diagrammatic conventions discussed in this chapter? **(b)** A block of metal that is known to be charged is now moved near the ball (Diagram 2 in Figure 14.98). The ball starts to swing toward the block of metal, as shown in Diagram 3 in Figure 14.98. Remember to read through the whole sequence before answering this question: Which of the diagrams in Figure 14.99 best shows the distribution of charge in and/or on the ball at this moment? **(c)** The ball briefly touches the charged metal block (Diagram 4 in Figure 14.98). Then the ball swings away from the block and hangs motionless at an angle, as shown in Diagram 5 in Figure 14.98. Which of the diagrams in Figure 14.99 best shows the distribution of charge in and/or on the ball at this moment? **(d)** Finally, the block is moved far away. A negatively charged rod is brought near the ball. The ball is repelled by the charged rod, as shown in Diagram 6 in Figure 14.98. Which of the diagrams in Figure 14.99 best shows the distribution of charge in and/or on the ball at this moment?

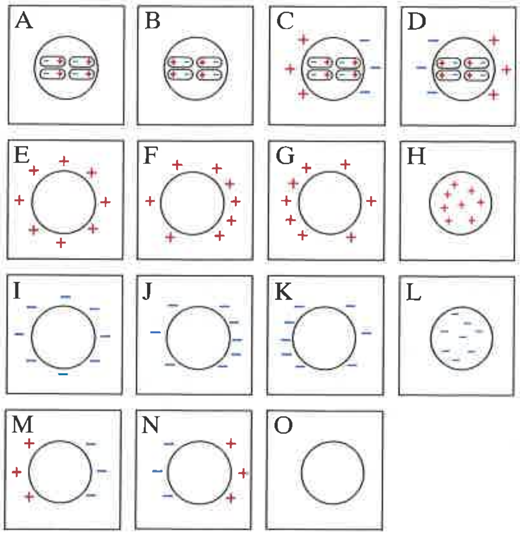

Figure 14.99

ANSWERS TO CHECKPOINTS

1 0; $-e = -1.6 \times 10^{-19}$ C

2 The student has forgotten to consider the superposition principle. Electric interactions go right through matter, so the effect of the positive nucleus is not blocked by the surrounding electron cloud. There are exactly as many protons in the nucleus as there are electrons, and normally the electron cloud is centered on the nucleus, so the net effect is zero.

3 About 2×10^{-15} m, about the diameter of a proton!

4 $2^{-5} = 1/32$

5 Negative tape is attracted to finger:

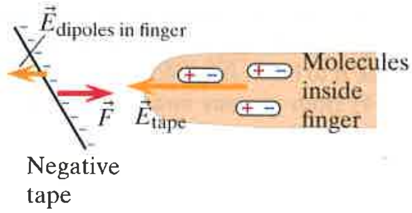

Figure 14.100

6 1.5×10^{-5} m/s

7 0.22 N/C

8 **(a)** Note shift of charge distribution; it is no longer uniform:

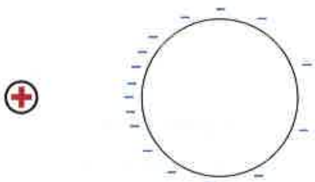

Figure 14.101

The net field is zero:

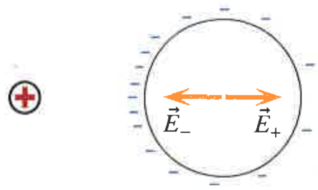

Figure 14.102

(b) Negative pen polarizes the neutral metal cylinder by shifting the electron sea; + charges are closer than − charges, so the pen exerts a net attraction on the cylinder.

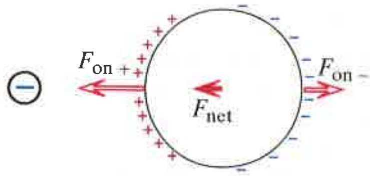

Figure 14.103

The net field is zero:

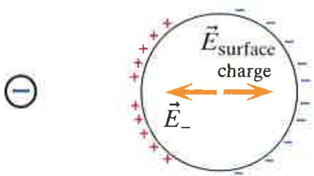

Figure 14.104

(c) Negative pen polarizes the neutral plastic cylinder by polarizing the molecules; + charges are closer than − charges, so the pen exerts a net attraction on the cylinder.