Chapter 18: ELECTRIC CHARGE and electric field

# 18.1 static electricity and charge: conservation of charge

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| 1. | | *Common static electricity involves charges ranging from nanocoulombs to microcoulombs. (a) How many electrons are needed to form a charge of –2.00 nC? (b) How many electrons must be removed from a neutral object to leave a net charge of ?* | | |
| Solution | | (a)  (b) | | |
| 2. | | *If  electrons move through a pocket calculator during a full day’s operation, how many coulombs of charge moved through it?* | | |
| Solution | |  | | |
| 3. | | *To start a car engine, the car battery moves  electrons through the starter motor. How many coulombs of charge were moved?* | | |
| Solution | |  | | |
| 4. | | *A certain lightning bolt moves 40.0 C of charge. How many fundamental units of charge  is this?* | | |
| Solution | |  | | |
| 18.2 conductors and insulators | | | | |
| 5. | | *Suppose a speck of dust in an electrostatic precipitator has  protons in it and has a net charge of –5.00 nC (a very large charge for a small speck). How many electrons does it have?* | | |
| Solution | |  | | |
| 6. | | *An amoeba has  protons and a net charge of 0.300 pC. (a) How many fewer electrons are there than protons? (b) If you paired them up, what fraction of the protons would have no electrons?* | | |
| Solution | | (a)  (b) | | |
| 7. | | *A 50.0 g ball of copper has a net charge of . What fraction of the copper’s electrons has been removed? (Each copper atom has 29 protons, and copper has an atomic mass of 63.5.)* | | |
| Solution | | The number of moles of copper is  so the number of protons, , is    Since there is the same number of electrons as protons in a neutral atom, before we remove the electrons to give the copper a net charge, we have  electrons.  Next we need to determine the number of electrons we removed to leave a net charge of . We need to remove  of charge, so the number of electrons to be removed is given by  electrons removed.  Lastly, the fraction of copper’s electrons removed is given by: | | |
| 8. | | *What net charge would you place on a 100 g piece of sulfur if you put an extra electron on 1 in  of its atoms? (Sulfur has an atomic mass of 32.1.)* | | |
| Solution | | The number of sulphur atoms, , is: | | |
| 9. | | *How many coulombs of positive charge are there in 4.00 kg of plutonium, given its atomic mass is 244 and that each plutonium atom has 94 protons?* | | |
| Solution | | Given *Z*= atomic number of an element = number of protons in elements: | | |
| 18.3 conductors and electric fields in static equilibrium | | | | |
| 10. | | *Sketch the electric field lines in the vicinity of the conductor in Figure 18.47, given the field was originally uniform and parallel to the object’s long axis. Is the resulting field small near the long side of the object?* | | |
| Solution | | Yes, the field is smaller near the long side of the object. | | |
| 11. | | *Sketch the electric field lines in the vicinity of the conductor in Figure 18.48 given the field was originally uniform and parallel to the object’s long axis. Is the resulting field small near the long side of the object?* | | |
| Solution | | Yes, the field is smaller near the long side of the object. | | |
| 12. | | *Sketch the electric field between the two conducting plates shown in Figure 18.49, given the top plate is positive and an equal amount of negative charge is on the bottom plate. Be certain to indicate the distribution of charge on the plates.* | | |
| Solution | |  | | |
| 13. | | *Sketch the electric field lines in the vicinity of the charged insulator in Figure 18.50 noting its nonuniform charge distribution.* | | |
| Solution | |  | | |
| 14. | | *What is the force on the charge located at  in Figure 18.51(a) given that ?* | | |
| Solution | |  | | |
| 15. | | *(a)Find the total electric field at  in Figure 18.51(b) given that . (b) Find the total electric field at  in Figure 18.51(b). (c) If the charges are allowed to move and eventually be brought to rest by friction, what will the final charge configuration be? (That is, will there be a single charge, double charge, etc., and what will its value(s) be?)* | | |
| Solution | | (a) Since and there is negative point charge at , the electric field at  will be negative infinity:  (b) and since    (c) The two charges will come together to be a charge of  and the two right charges will come together to form one charge of , so eventually the charges will come together to form one charge of . | | |
| 16. | | *(a) Find the electric field at  in Figure 18.51(a), given that . (b) At what position between 3.00 and 8.00 cm is the total electric field the same as that for  alone? (c) Can the electric field be zero anywhere between 0.00 and 8.00 cm? (d) At very large positive or negative values of x, the electric field approaches zero in both (a) and (b). In which does it most rapidly approach zero and why? (e) At what position to the right of 11.0 cm is the total electric field zero, other than at infinity? (Hint: A graphing calculator can yield considerable insight in this problem.)* | | |
| Solution | | (a)  (b) For the total electric field to have the same value as it would be for the charge alone, we need to find the place where the two positive charges alone create a zero electric field. This point is halfway between the two points or at  (c) No, the electric field cannot be zero anywhere between 0.00cm and 8.00cm.  (d) At very large positive or negative values of *x*, the electric field approaches zero because the distance from the charges approaches infinity. The electric field approaches zero more rapidly in Figure 18.52 because the net charge is zero.  (e) For a position greater than 11.0 cm, we must find a value of *x* that satisfies:  where *x* has units of centimeters. We can then graph this function, using a graphing calculator or graphing program, to determine the values of *x* that yield  From the graph we find that the electric field is zero at | | |
| 17. | | *(a) Find the total Coulomb force on a charge of 2.00 nC located at  in Figure 18.51(b), given that . (b) Find the x-position at which the electric field is zero in Figure 18.51(b).* | | |
| Solution | | (a) The net force is given by  , to the right.  Substituting in the values given:    (b) The only possible location where the total electric field could be zero is between 5.00 and 8.00 cm. For the total electric field to be zero between 5.00 and 8.00 cm, we know that .  Dividing by common factors and ignoring units (but remembering *x* has a unit of cm), we can get a simplified expression:  We can graph this function, using a graphing calculator or graphing program to determine the values of *x* that yield  Therefore the total electric field is zero at 6.07 cm. | | |
| 18. | | *(a) Using the symmetry of the arrangement, determine the direction of the force on  in the figure below, given that  and . (b) Calculate the magnitude of the force on the charge , given that the square is 10.0 cm on a side and .* | | |
| Solution | | (a) Due to symmetry the net force on *q* will be straight down, since  and  are positive and  and  are negative and all have the same magnitude.  and  will force the charge downward and  and  will pull the charge downward also.  (b) Since the square is 10.0cm on a side, the distance to the charge  will be  so    45 degrees below *x*-axis.  The total force will be: | | |
| 19. | | *(a) Using the symmetry of the arrangement, determine the direction of the electric field at the center of the square in Figure 18.52, given that*  *and . (b) Calculate the magnitude of the electric field at the location of , given that the square is 5.00 cm on a side.* | | |
| Solution | | (a) The electric field at the center of the square will be straight up, since  and  are negative and  and  are positive and all have the same magnitude.  (b) Since the square is 5.00 cm on a side, the distance to the center of the square is , so using , the electric field due to upper left hand charge is:    45 degrees below *x*-axis, or  above *x*-axis.  The other three fields will have the same magnitude, only in different directions. From part (a) we know that the only component that we need to calculate is the *y*-component, since the *x*-component will cancel. The total electric field at the center will then be: | | |
| 20. | | *Find the electric field at the location of  in Figure 18.52 given that , , and the square is 20.0 cm on a side.* | | |
| Solution | | in the *x*-dir;  in the +*y* direction.  above the *x*-axis.  below the *x*-axis.  Summing gives:    So the electric field at the location of *q* is  45 degrees above the *x*-axis. | | |
| 21. | | *Find the total Coulomb force on the charge  in Figure 18.52, given that , , , , and . The square is 50.0 cm on a side.* | | |
| Solution | | above the *x*-axis.  above the +*x*-axis,  below the -*x*-axis, and  below the +*x*-axis.  Summing up the components gives:    So the total coulomb force on the charge  is in the | | |
| 22. | | *(a) Find the electric field at the location of  in Figure 18.53, given that  and . (b) What is the force on , given that ?* | | |
| Solution | | (a)  above the -*x*-axis and  below the –*x*-axis. Summing up the components gives:    ,  So the total electric field at the location of  is  and  above the –*x*-axis, or  above the –*x*-axis.  (b)  above the –*x*-axis. | | |
| 23. | | *(a) Find the electric field at the center of the triangular configuration of charges in Figure 18.53, given that , , and . (b) Is there any combination of charges, other than , that will produce a zero strength electric field at the center of the triangular configuration?* | | |
| Solution | | (a) To determine the electric field at the center, we first must determine the distance from each of the charges to the center of the triangle. Since the triangle is equilateral, the center of the triangle will be halfway across the base and 1/3 of the way up the height. To determine the height use the Pythagorean theorem, or the height is given by . So the distance from each charge to the center of the triangle is 2/3 of 21.7 cm, or  at a  angle below the horizontal,  at a  angle below the horizontal, and  at a angle above the horizontal. Adding the vectors by components gives:    So that the electric field is given by: and    below the horizontal.  (b) No, there are no combinations other than  that will produce a zero strength field at the center of the triangular configuration because of the vector nature of the electric field. | | |
| 18.4 coulomb’s law | | | | |
| 24. | | *What is the repulsive force between two pith balls that are 8.00 cm apart and have equal charges of – 30.0 nC?* | | |
| Solution | |  | | |
| 25. | | *(a) How strong is the attractive force between a glass rod with a  charge and a silk cloth with a charge, which are 12.0 cm apart, using the approximation that they act like point charges? (b) Discuss how the answer to this problem might be affected if the charges are distributed over some area and do not act like point charges.* | | |
| Solution | | (a)  (b) Assuming the center of mass is separated by 12.0 cm, the answer in part (a) is only true if the charges are concentrated at the center of mass. If, however, the charges are distributed over some area, there will be a concentration of charge along the side closest to the oppositely charged object. This effect will increase the net force. | | |
| 26. | | *Two point charges exert a 5.00 N force on each other. What will the force become if the distance between them is increased by a factor of three?* | | |
| Solution | |  | | |
| 27. | | *Two point charges are brought closer together, increasing the force between them by a factor of 25. By what factor was their separation decreased?* | | |
| Solution | | Using we see that force is inversely proportional to the separation distance squared, so that  Since we now the ratio of the forces, we can determine the ratio of the separation distances: so that . The separation decreased by a factor of 5. | | |
| 28. | | *How far apart must two point charges of 75.0 nC (typical of static electricity) be to have a force of 1.00 N between them?* | | |
| Solution | |  | | |
| 29. | | *If two equal charges each of 1 C each are separated in air by a distance of 1 km, what is the magnitude of the force acting between them? You will see that even at a distance as large as 1 km, the repulsive force is substantial because 1 C is a very significant amount of charge.* | | |
| Solution | |  | | |
| 30. | | *A test charge of  is placed halfway between a charge of  and another of  separated by 10 cm. (a) What is the magnitude of the force on the test charge? (b) What is the direction of this force (away from or toward the  charge)?* | | |
| Solution | | (a)  (b) The direction of the force is away from the  charge. | | |
| 31. | | *Bare free charges do not remain stationary when close together. To illustrate this, calculate the acceleration of two isolated protons separated by 2.00 nm (a typical distance between gas atoms). Explicitly show how you follow the steps in the Problem-Solving Strategy for electrostatics.* | | |
| Solution | |  | | |
| 32. | | *(a) By what factor must you change the distance between two point charges to change the force between them by a factor of 10? (b) Explain how the distance can either increase or decrease by this factor and still cause a factor of 10 change in the force.* | | |
| Solution | | (a)  so that  (b) If the distance increases by 3.16, then the force will decrease by a factor of 10; if the distance decreases by 3.16, then the force will increase by a factor of 10. Either way, the force changes by a factor of 10. | | |
| 33. | | *Suppose you have a total charge  that you can split in any manner. Once split, the separation distance is fixed. How do you split the charge to achieve the greatest force?* | | |
| Solution | | This represents a quadratic equation in , which would graph as a parabola with its peak midway between the two values that cause , namely  and . Thus, the maximum value occurs at  Therefore, splitting the charge evenly produces the greatest force. | | |
| 34. | | *(a) Common transparent tape becomes charged when pulled from a dispenser. If one piece is placed above another, the repulsive force can be great enough to support the top piece’s weight. Assuming equal point charges (only an approximation), calculate the magnitude of the charge if electrostatic force is great enough to support the weight of a 10.0 mg piece of tape held 1.00 cm above another. (b) Discuss whether the magnitude of this charge is consistent with what is typical of static electricity.* | | |
| Solution | | (a)  (b) This charge is approximately 1nC, which is consistent with the magnitude of charge of typical static electricity. | | |
| 35. | | *(a) Find the ratio of the electrostatic to gravitational force between two electrons. (b) What is this ratio for two protons? (c) Why is the ratio different for electrons and protons?* | | |
| Solution | | (a) Since .  For electrons  so that    (b) For protons,  so that  (c) The ratio is different for electrons and protons because the masses are different. | | |
| 36. | | *At what distance is the electrostatic force between two protons equal to the weight of one proton?* | | |
| Solution | |  | | |
| 37. | | *A certain five cent coin contains 5.00 g of nickel. What fraction of the nickel atoms’ electrons, removed and placed 1.00 m above it, would support the weight of this coin? The atomic mass of nickel is 58.7, and each nickel atom contains 28 electrons and 28 protons.* | | |
| Solution | | The number of electrons,  in the nickel is .  Assume the number of electrons removed from the nickel is *N*. Then the charge of the removed electrons is  and the charge of the remaining positively charged nickel is  Thus,  Note that there is a minus sign in front of *mg* because the attractive force between the electrons and the positively charged nickel will be equal and opposite in direction to the gravitational force. Continuing so that  Therefore, | | |
| 38. | | *(a) Two point charges totaling  exert a repulsive force of 0.150 N on one another when separated by 0.500 m. What is the charge on each? (b) What is the charge on each if the force is attractive?* | | |
| Solution | | (a) so that    (b)  so thatand | | |
| 39. | | *Point charges of  and  are placed 0.250 m apart. (a) Where can a third charge be placed so that the net force on it is zero? (b) What if both charges are positive?* | | |
| Solution | | (a) We know that since the negative charge is smaller, the third charge should be placed to the right of the negative charge if the net force on it is to be zero. So if we want, we can use  to write the forces in terms of distances:  , or since , or  so that  and finally,  The charge must be placed at a distance of 0.859 m to the far side of the negative charge.  (b) This time we know that the charge must be placed between the two positive charges and closer to the  charge for the net force to be zero. So if we want , we can again use  to write the forces in terms of distances:  Or since  or  , or, and finally  The charge must be placed at a distance of 0.109m from the  charge. | | |
| 40. | | *Two point charges  and  are  apart, and their total charge is . (a) If the force of repulsion between them is 0.075 N, what are magnitudes of the two charges? (b) If one charge attracts the other with a force of 0.525 N, what are the magnitudes of the two charges? Note that you may need to solve a quadratic equation to reach your answer.* | | |
| Solution | | (a)  Use the quadratic formula:  So the two possibilities are:  (b)  Same method as part (a):    Use the quadratic formula. The two possibilities are: | | |
| 18.5 ELECTRIC FIELD: CONCEPT OF A FIELD REVISITED | | | | |
| 41. | | *What is the magnitude and direction of an electric field that exerts a  upward force on a  charge?* | | |
| Solution | |  | | |
| 42. | | *What is the magnitude and direction of the force exerted on a  charge by a 250 N/C electric field that points due east?* | | |
| Solution | |  | | |
| 43. | | *Calculate the magnitude of the electric field 2.00 m from a point charge of 5.00 mC (such as found on the terminal of a Van de Graaff).* | | |
| Solution | |  | | |
| 44. | | *(a) What magnitude point charge creates a 10,000 N/C electric field at a distance of 0.250 m? (b) How large is the field at 10.0 m?* | | |
| Solution | | (a)  (b) | | |
| 45. | | *Calculate the initial (from rest) acceleration of a proton in a  electric field (such as created by a research Van de Graaff). Explicitly show how you follow the steps in the Problem-Solving Strategy for electrostatics.* | | |
| Solution | |  | | |
| 46. | | *(a) Find the direction and magnitude of an electric field that exerts a  westward force on an electron. (b) What magnitude and direction force does this field exert on a proton?* | | |
| Solution | | (a)  (b) | | |
| 18.6 ELECTRIC FIELD lines: multiple charges | | | | |
| 47. | | | *(a) Sketch the electric field lines near a point charge . (b) Do the same for a point charge .* | |
| Solution | | | (a)  (b) | |
| 48. | | | *Sketch the electric field lines a long distance from the charge distributions shown in Figure 18.26(a) and (b).* | |
| Solution | | | (a)  (b)  No net charge is seen from far away. | |
| 49. | | | *Figure 18.47 shows the electric field lines near two charges  and . What is the ratio of their magnitudes? (b) Sketch the electric field lines a long distance from the charges shown in the figure.* | |
| Solution | | | (a)  (b) A long distance away, the two charges appear as one charge, with total charge , where  is some basic unit of charge. The field will look like that of one of the point charges in Figure 18.23, but with 11 lines directed away. | |
| 50. | | | *Sketch the electric field lines in the vicinity of two opposite charges, where the negative charge is three times greater in magnitude than the positive. (See Figure 18.47 for a similar situation.)* | |
| Solution | | |  | |

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| 18.8 applications of electrostatics | |
| 51. | *(a) What is the electric field 5.00 m from the center of the terminal of a Van de Graaff with a 3.00 mC charge, noting that the field is equivalent to that of a point charge at the center of the terminal? (b) At this distance, what force does the field exert on a  charge on the Van de Graaff’s belt?* |
| Solution | (a)  (b) |
| 52. | *(a) What is the direction and magnitude of an electric field that supports the weight of a free electron near the surface of Earth? (b) Discuss what the small value for this field implies regarding the relative strength of the gravitational and electrostatic forces.* |
| Solution | (a)  Electric field is towards the surface of earth.  (b) The coulomb force is extraordinarily stronger than gravity. |
| 53. | *A simple and common technique for accelerating electrons is shown in Figure 18.55, where there is a uniform electric field between two plates. Electrons are released, usually from a hot filament, near the negative plate, and there is a small hole in the positive plate that allows the electrons to continue moving. (a) Calculate the acceleration of the electron if the field strength is . (b) Explain why the electron will not be pulled back to the positive plate once it moves through the hole.* |
| Solution | (a)  (b) There is no field outside the plates. |
| 54. | *Earth has a net charge that produces an electric field of approximately 150 N/C downward at its surface. (a) What is the magnitude and sign of the excess charge, noting the electric field of a conducting sphere is equivalent to a point charge at its center? (b) What acceleration will the field produce on a free electron near Earth’s surface? (c) What mass object with a single extra electron will have its weight supported by this field?* |
| Solution | (a)  (b)  (c) |
| 55. | *Point charges of  and  are placed 0.500 m apart. (a) At what point along the line between them is the electric field zero? (b) What is the electric field halfway between them?* |
| Solution | (a)  And finally solving for *x* gives:  from  charge.  (b)  towards the larger charge. |
| 56. | *What can you say about two charges  and , if the electric field one-fourth of the way from  to  is zero?* |
| Solution | If the electric field is zero 1/4 from the way of  and , then we know from  that  so that  The charge  is 9 times larger than . |
| 57. | ***Integrated Concepts*** *Calculate the angular velocity*  *of an electron orbiting a proton in the hydrogen atom, given the radius of the orbit is . You may assume that the proton is stationary and the centripetal force is supplied by Coulomb attraction.* |
| Solution |  |
| 58. | ***Integrated Concepts*** *An electron has an initial velocity of  in a uniform  strength electric field. The field accelerates the electron in the direction opposite to its initial velocity. (a) What is the direction of the electric field? (b) How far does the electron travel before coming to rest? (c) How long does it take the electron to come to rest? (d) What is the electron’s velocity when it returns to its starting point?* |
| Solution | (a) The field is in the direction of the electron’s initial velocity.  (b)  (c)  (d) |
| 59. | ***Integrated Concepts*** *The practical limit to an electric field in air is about . Above this strength, sparking takes place because air begins to ionize and charges flow, reducing the field. (a) Calculate the distance a free proton must travel in this field to reach  of the speed of light, starting from rest. (b) Is this practical in air, or must it occur in a vacuum?* |
| Solution | (a)  (b) No, it is impractical in air. A proton would collide with an air molecule before it could travel this far. |
| 60. | ***Integrated Concepts*** *A 5.00 g charged insulating ball hangs on a 30.0 cm long string in a uniform horizontal electric field as shown in Figure 18.56. Given the charge on the ball is , find the strength of the field.* |
| Solution |  |
| 61. | ***Integrated Concepts*** *Figure 18.57 shows an electron passing between two charged metal plates that create an 100 N/C vertical electric field perpendicular to the electron’s original horizontal velocity. (These can be used to change the electron’s direction, such as in an oscilloscope.) The initial speed of the electron is , and the horizontal distance it travels in the uniform field is 4.00 cm. (a) What is its vertical deflection? (b) What is the vertical component of its final velocity? (c) At what angle does it exit? Neglect any edge effects.* |
| Solution | (a)  (b)  (c) |
| 62. | ***Integrated Concepts*** *The classic Millikan oil drop experiment was the first to obtain an accurate measurement of the charge on an electron. In it, oil drops were suspended against the gravitational force by a vertical electric field. (See Figure 18.58.) Given the oil drop to be  in radius and have a density of : (a) Find the weight of the drop. (b) If the drop has a single excess electron, find the electric field strength needed to balance its weight.* |
| Solution | Let = density of oil drop, and = volume of oil drop.  (a)  (b) |
| 63. | ***Integrated Concepts*** *(a) In Figure 18.59, four equal charges  lie on the corners of a square. A fifth charge  is on a mass  directly above the center of the square, at a height equal to the length  of one side of the square. Determine the magnitude of  in terms of , , and , if the Coulomb force is to equal the weight of . (b) Is this equilibrium stable or unstable? Discuss.* |
| Solution | (a) Because of symmetry, the only force that does not cancel is the vertical component of the force, so we need only calculate the vertical component effect of one of the corner charges and multiply by four to get the total force. The distance from any corner charge *q* to the charge *Q* is  Therefore, the magnitude of the force due to one charge is: , acting along the line from *q* to *Q*. So, the component of the force acting in the vertical direction is: , where , so that the total force in the vertical direction is given by . Now, if this force is balanced by the force of gravity, then  and  so that . |
| 64. | ***Unreasonable Results*** *(a) Calculate the electric field strength near a 10.0 cm diameter conducting sphere that has 1.00 C of excess charge on it. (b) What is unreasonable about this result? (c) Which assumptions are responsible?* |
| Solution | (a)  (b) The field is too large to be in air.  (c) 1.00 C is too great for an excess charge on the sphere's surface. |
| 65. | ***Unreasonable Results*** *(a) Two 0.500 g raindrops in a thunderhead are 1.00 cm apart when they each acquire 1.00 mC charges. Find their acceleration. (b) What is unreasonable about this result? (c) Which premise or assumption is responsible?* |
| Solution | (a)  (b) The resulting acceleration is unreasonably large; the raindrops would not stay together.  (c) The assumed charge of  is much too great; typical static electricity is on the order of  or less. |
| 66. | ***Unreasonable Results*** *A wrecking yard inventor wants to pick up cars by charging a 0.400 m diameter ball and inducing an equal and opposite charge on the car. If a car has a 1000 kg mass and the ball is to be able to lift it from a distance of 1.00 m: (a) What minimum charge must be used? (b) What is the electric field near the surface of the ball? (c) Why are these results unreasonable? (d) Which premise or assumption is responsible?* |
| Solution | (a)  (b)  (c) It would be impractical to place that much excess charge on a wrecking ball. Even so, the necessary *E*-field strength is  much too great to be created in air.  (d) It is unreasonable that one can lift heavy objects with static electricity. |

# Test Prep For AP® Courses

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| 1. | *When a glass rod is rubbed against silk, which of the following statements is true?*  (A) Electrons are removed from the silk.  (B) Electrons are removed from the rod.  (C) Protons are removed from the silk.  (D) Protons are removed from the rod. |
| Solution | (b) |
| 2. | *In an experiment, three microscopic latex spheres are sprayed into a chamber and become charged with +3e, +5e, and −3e, respectively. Later, all three spheres collide simultaneously and then separate. Which of the following are possible values for the final charges on the spheres? Select two answers.*  X Y Z  (A) +4*e* −4*e* +5*e*  (B) −4*e* +4.5*e* +5.5*e*  (C) +5*e* −8*e* +7*e*  (D) +6*e* +6*e* −7*e* |
| Solution | (a), (d) |
| 3. | *If objects X and Y attract each other, which of the following will be false?*   1. X has positive charge and Y has negative charge. 2. X has negative charge and Y has positive charge. 3. X and Y both have positive charge. 4. X is neutral and Y has a charge. |
| Solution | (c) |
| 4. | *Suppose a positively charged object A is brought in contact with an uncharged object B in a closed system. What type of charge will be left on object B?*  (A) negative  (B) positive  (C) neutral  (D) cannot be determined |
| Solution | (b) |
| 5. | *What will be the net charge on an object which attracts neutral pieces of paper but repels a negatively charged balloon?*   1. negative 2. positive 3. neutral 4. cannot be determined |
| Solution | (a) |
| 6. | *When two neutral objects are rubbed against each other, the first one gains a net charge of 3e. Which of the following statements is true?*   1. The second object gains 3*e* and is negatively charged. 2. The second object loses 3*e* and is negatively charged. 3. The second object gains 3*e* and is positively charged. 4. The second object loses 3*e* and is positively charged. |
| Solution | (d) |
| 7. | *In an experiment, a student runs a comb through his hair several times and brings it close to small pieces of paper. Which of the following will he observe?*   1. Pieces of paper repel the comb. 2. Pieces of paper are attracted to the comb. 3. Some pieces of paper are attracted and some repel the comb. 4. There is no attraction or repulsion between the pieces of paper and the comb. |
| Solution | (b) |
| 8. | *In an experiment a negatively charged balloon (balloon X) is repelled by another charged balloon Y. However, an object Z is attracted to balloon Y. Which of the following can be the charge on Z? Select two answers.*   * 1. negative   2. positive   3. neutral   4. cannot be determined |
| Solution | (b), (c) |
| 9. | *Suppose an object has a charge of 1 C and gains 6.88×1018 electrons.*   * 1. *What will be the net charge of the object?*   2. *If the object has gained electrons from a neutral object, what will be the charge on the neutral object?*  1. *Find and explain the relationship between the total charges of the two objects before and after the transfer.* 2. *When a third object is brought in contact with the first object (after it gains the electrons), the resulting charge on the third object is 0.4 C. What was its initial charge?* |
| Solution | a) -0.1 C, b) 1.1 C, c) Both charges will be equal to 1 C, law of conservation of charge, d) 0.9 C |
| 10. | *The charges on two identical metal spheres (placed in a closed system) are -2.4×10−17 C and -4.8×10−17 C.*   1. *How many electrons will be equivalent to the charge on each sphere?* 2. *If the two spheres are brought in contact and then separated, find the charge on each sphere.* 3. *Calculate the number of electrons that would be equivalent to the resulting charge on each sphere.* |
| Solution | a) 150 electrons and 300 electrons, b) -3.6×10−17, c) 225 electrons |
| 11. | *In an experiment the following observations are made by a student for four charged objects W, X, Y, and Z:*   * *A glass rod rubbed with silk attracts W.* * *W attracts Z but repels X.* * *X attracts Z but repels Y.* * *Y attracts W and Z.*   *Estimate whether the charges on each of the four objects are positive, negative, or neutral.* |
| Solution | W is negative, X is positive, Y is negative, Z is neutral. |
| 12. | *Some students experimenting with an uncharged metal sphere want to give the sphere a net charge using a charged aluminum pie plate. Which of the following steps would give the sphere a net charge of the same sign as the pie plate?*  (A) bringing the pie plate close to, but not touching the metal sphere, then moving the pie plate away.  (B) bringing the pie plate close to, but not touching, the metal sphere, then momentarily touching a grounding wire to the metal sphere.  (C) bringing the pie plate close to, but not touching, the metal sphere, then momentarily touching a grounding wire to the pie plate.  (D) touching the pie plate to the metal sphere. |
| Solution | (d) |
| 13. | *When the balloon is brought closer to the sphere, there will be a redistribution of charges. What is this phenomena called?*   * 1. electrostatic repulsion   2. conduction   3. polarization   4. none of the above |
| Solution | (c) |
| 14. | *What will be the charge at Y (i.e., the part of the sphere furthest from the balloon)?*   1. positive 2. negative 3. zero 4. It can be positive or negative depending on the material. |
| Solution | (a) |
| 15. | *What will be the net charge on the sphere?*   * 1. positive   2. negative   3. zero   4. It can be positive or negative depending on the material. |
| Solution | (c) |
| 16. | *If Y is grounded while the balloon is still close to X, which of the following will be true?*   * 1. Electrons will flow from the sphere to the ground.   2. Electrons will flow from the ground to the sphere.   3. Protons will flow from the sphere to the ground.   4. Protons will flow from the ground to the sphere. |
| Solution | (b) |
| 17. | *If the balloon is moved away after grounding, what will be the net charge on the sphere?*   * + - * 1. positive         2. negative         3. zero         4. It can be positive or negative depending on the material. |
| Solution | (b) |
| 18. | *A positively charged rod is used to charge a sphere by induction. Which of the following is true?*  (A) The sphere must be a conductor.  (B) The sphere must be an insulator.  (C) The sphere can be a conductor or insulator but must be connected to ground.  (D) The sphere can be a conductor or insulator but must be already charged. |
| Solution | (a) |
| 19. | [Figure\_Ch18\_S02]  *As shown in the figure above, two metal balls are suspended and a negatively charged rod is brought close to them.*   * 1. *If the two balls are in contact with each other what will be the charges on each ball?*   2. *Explain how the balls get these charges.*   3. *What will happen to the charge on the second ball (i.e., the ball further away from the rod) if it is momentarily grounded while the rod is still there?*   4. *If (instead of grounding) the second ball is moved away and then the rod is removed from the first ball, will the two balls have induced charges? If yes, what will be the charges? If no, why not?* |
| Solution | a) Ball 1 will have positive charge and Ball 2 will have negative charge. b) The negatively charged rod attracts positive charge of Ball 1. The electrons of Ball 1 are transferred to Ball 2, making it negatively charged. c) If Ball 2 is grounded while the rod is still there, it will lose its negative charge to the ground. d) Yes, Ball 1 will be positively charged and Ball 2 will be negatively charge. |
| 20. | *Two experiments are performed using positively charged glass rods and neutral electroscopes. In the first experiment the rod is brought in contact with the electroscope. In the second experiment the rod is only brought close to the electroscope but not in contact. However, while the rod is close, the electroscope is momentarily grounded and then the rod is removed. In both experiments the needles of the electroscopes deflect, which indicates the presence of charges.*   * 1. What is the charging method in each of the two experiments?   2. What is the net charge on the electroscope in the first experiment? Explain how the electroscope obtains that charge.   3. Is the net charge on the electroscope in the second experiment different from that of the first experiment? Explain why. |
| Solution | a) The charging in the first experiment is by contact and the charging in the second experiment is by induction. b) The electroscope has a positive charge. When the positively charged rod is touched against the electroscope, electrons are attracted and transferred to the rod, reducing the net charge on the glass rod and leaving the electroscope positively charged. c) Yes, the electroscope has a negative charge. When the positively charged rod is brought close to the electroscope, electrons are attracted close to the rod. When the electroscope is grounded, electrons are attracted from the earth to the electroscope. When the ground connection is broken and the rod is removed, the electroscope has an induced negative charge. |
| 21. | *What will be the force be if the distance between them is halved?*   * + - * 1. 4*F*         2. 2*F*         3. *F*/4         4. *F*/2 |
| Solution | (a) |
| 22. | *Which of the following is false?*   1. If the charge of one of the particles is doubled and second is unchanged, the force will become 2*F*. 2. If the charge of one of the particles is doubled and second is halved, the force will remain *F*. 3. If the charge of both the particles is doubled, the force will become 4*F*. 4. None of the above. |
| Solution | (d) |
| 23. | *Which of the following is true about the gravitational force between the particles?*   1. It will be 3.25×10−38 *F*. 2. It will be 3.25×1038 *F*. 3. It will be equal to *F*. 4. It is not possible to determine the gravitational force as the masses of the particles are not given. |
| Solution | (d) |
| 24. | *Two massive, positively charged particles are initially held a fixed distance apart. When they are moved farther apart, the magnitude of their mutual gravitational force changes by a factor of n. Which of the following indicates the factor by which the magnitude of their mutual electrostatic force changes?*  (A) 1/*n*2  (B) 1/*n*  (C) *n*  (D) *n*2 |
| Solution | (c) |
| 25. | * 1. *What is the electrostatic force between two charges of 1 C each, separated by a distance of 0.5 m?*   2. *How will this force change if the distance is increased to 1 m?* |
| Solution | a) 3.60×1010 N, b) It will become 1/4 of the original value; hence it will be equal to 8.99×109 N |
| 26. | 1. *Find the ratio of the electrostatic force to the gravitational force between two electrons.* 2. *Will this ratio change if the two electrons are replaced by protons? If yes, find the new ratio.* |
| Solution | a) 4.16×1042, b) yes, because the masses are different, 1.24×1036 |
| 27. | *What is the electric field of the +q particle at the same distance and what force does it exert on the +2q particle?*   1. *E*/2, *F*/2 2. *E*, *F*/2 3. *E*/2, *F* 4. *E*, *F* |
| Solution | (c) |
| 28. | *When the +q particle is replaced by a +3q particle, what will be the electric field and force from the +2q particle experienced by the +3q particle?*   1. *E*/3, 3*F* 2. *E*, 3*F* 3. *E*/3, *F* 4. *E*, *F* |
| Solution | (b) |
| 29. | *The direction of the electric field of a negative charge is*   1. inward for both positive and negative charges. 2. outward for both positive and negative charges. 3. inward for other positive charges and outward for other negative charges. 4. outward for other positive charges and inward for other negative charges. |
| Solution | (a) |
| 30. | *The force responsible for holding an atom together is*   1. frictional 2. electric 3. gravitational 4. magnetic |
| Solution | (b) |
| 31. | *When a positively charged particle exerts an inward force on another particle P, what will be the charge of P?*   1. positive 2. negative 3. neutral 4. cannot be determined |
| Solution | (b) |
| 32. | *Find the force exerted due to a particle having a charge of 3.2×10−19 C on another identical particle 5 cm away.* |
| Solution | 3.68×10−25 N |
| 33. | *Suppose that the force exerted on an electron is 5.6×10−17 N, directed to the east.*   * 1. *Find the magnitude of the electric field that exerts the force.*   2. *What will be the direction of the electric field?*   3. *If the electron is replaced by a proton, what will be the magnitude of force exerted?*   4. *What will be the direction of force on the proton?* |
| Solution | a) 350 N/C, b) west, c) 5.6×10−17 N, d) west. |
| 34. | [Figure\_Ch18\_S03]  *An electric dipole (with +2q and –2q as the two charges) is shown in the figure above. A third charge, −q is placed equidistant from the dipole charges. What will be the direction of the net force on the third charge?*  (A)  (B)  (C)  (D) |
| Solution | (a) |
| 35. | *What is the magnitude of force exerted by object W on Z?*  (A) *F*/7  (B) *F*/5  (C) *F*/3  (D) *F*/2 |
| Solution | (b) |
| 36. | *What is the magnitude of the net force exerted on object X by objects W, Y, and Z?*  (A) *F*/4  (B) *F*/2  (C) 9*F*/4  (D) 3*F* |
| Solution | (a) |
| 37. | [Figure\_Ch18\_S05]  *The figure above represents the electric field in the vicinity of three small charged objects, R, S, and T. The objects have charges −q, +2q, and −q, respectively, and are located on the x-axis at −d, 0, and d. Field vectors of very large magnitude are omitted for clarity.*  *(a) (i) Briefly describe the characteristics of the field diagram that indicate that the sign of the charges of objects R and T is negative and that the sign of the charge of object S is positive.*  *(ii) Briefly describe the characteristics of the field diagram that indicate that the magnitudes of the charges of objects R and T are equal and that the magnitude of the charge of object S is about twice that of objects R and T.*  *For the following parts, an electric field directed to the right is defined to be positive.*  *(b) On the axes below, sketch a graph of the electric field E along the x-axis as a function of position x.*    [Figure\_Ch18\_S06]  *(c) Write an expression for the electric field E along the x-axis as a function of position x in the region between objects S and T in terms of q, d, and fundamental constants, as appropriate.*  *(d) Your classmate tells you there is a point between S and T where the electric field is zero. Determine whether this statement is true, and explain your reasoning using two of the representations from parts (a), (b), or (c).* |
| Solution | (a) i) Field vectors near objects point toward negatively charged objects and away from positively charged objects.  (a) ii) The vectors closest to *R* and *T* are about the same length and start at about the same distance. We have that , so the charge on *R* is about the same as the charge on *T*. The closest vectors around *S* are about the same length as those around *R* and *T*. The vectors near *S* start at about 6 units away, while vectors near *R* and *T* start at about 4 units. We have that , so, and so the charge on *S* is about twice that on *R*and *T*.  (b)    [Figure\_Ch18\_S07]  (c)    (d) The statement is not true. The vector diagram shows field vectors in this region with nonzero length, and the vectors not shown have even greater lengths. The equation in part (c) shows that, when , the denominator of the negative term is always greater than the denominator of the third term, but the numerator is the same. So the negative term always has a smaller magnitude than the third term and since the second term is positive the sum of the terms is always positive. |
| 38. | *An electric field due to a positively charged spherical conductor is shown above. Where will the electric field be weakest?*  (A) Point A  (B) Point B  (C) Point C  (D) Same at all points |
| Solution | (c) |
| 39. | *The electric field created by two parallel metal plates is shown above. Where will the electric field be strongest?*  (A) Point A  (B) Point B  (C) Point C  (D) Same at all points |
| Solution | (d) |
| 40. | *Suppose that the electric field experienced due to a positively charged small spherical conductor at a certain distance is E. What will be the percentage change in electric field experienced at thrice the distance if the charge on the conductor is doubled?* |
| Solution | decrease by 77.78%. |
| 41. | *The classic Millikan oil drop experiment setup is shown above. In this experiment oil drops are suspended in a vertical electric field against the gravitational force to measure their charge. If the mass of a negatively charged drop suspended in an electric field of 1.18×10−4 N/C strength is 3.85×10−21 g, find the number of excess electrons in the drop.* |
| Solution | 2 |

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