End-of-Chapter Exercises

Exercises 1 – 14 are mainly conceptual questions designed to see if you have understood the main concepts of the chapter. Treat all charged balls as point charges.

1. While you are solving a physics problem, you calculate that the charge on a particular object has a value of $+2.5\times10^{-22}$ C . Can this be correct? Choose the one correct statement about this from the set of three options below. Note that *e* represents the magnitude of the charge on the electron.

A – Yes, this answer could be correct.
B – No, this answer cannot be correct because the charge represents a small fraction of *e*.
C – No, this answer cannot be correct. The value has a magnitude larger than *e*, but it does not represent an integer multiple of *e*.

2. You have three identical metal spheres that have different initial net charges. Sphere A has a net charge of +5*Q*; sphere B has a net charge of –3*Q*; and sphere C has a net charge of +6*Q*. You first touch sphere B to sphere A, and then separate them; you then touch sphere A to sphere C, and then separate them; and finally you touch sphere C to sphere B, and then separate them. (a) Assuming no charge is transferred to you, what is the total combined charge on the three spheres at the end of the process? (b) What is the charge on each one of the spheres at the end of the process?

3. Consider again the system of three charged metal spheres in Exercise 2. You can set their initial charges to be whatever you wish, but you touch them together as described in the previous problem. (a) Is it possible for each sphere to end up with the same non-zero net charge? If so, give an example. (b) Is it possible for each sphere to end up with a different amount of charge? If so, give an example. (c) Is it possible for the sign of the charge on one sphere to be opposite to the charge on the other two spheres, at the end of the process? If so, give an example.

4. A small charged ball with a charge of +5*Q* is located at a distance of 2.0 m from a charged ball with a charge of +*Q*. Which ball exerts a larger-magnitude force on the other? Justify your answer.

5. Ball A is charged, and so is ball B. The two balls are separated by a distance of *d*, and they can be treated as point charges. Which of the following changes, done individually, would cause the force that ball B exerts on ball A to double? If the change does not cause a doubling of the force state explicitly what effect the change has. (a) Double the charge on ball B. (b) Double the charge on ball A. (c) Double the charge on both balls. (d) Decrease the separation between the balls to *d*/2.

6. The electric field in the region shown in Figure 16.19 is produced by a single point charge, but the location of that point charge is unknown. At the point ($x = 1$, $y = 1$), we know that the electric field is directed to the right. (a) If this is all we knew about the field, what could we say about the location and sign of the point charge? (b) We also know that, at the point ($x = 3$, $y = 3$), the electric field is directed down. With this additional information, what can we say about the location and sign of the point charge?

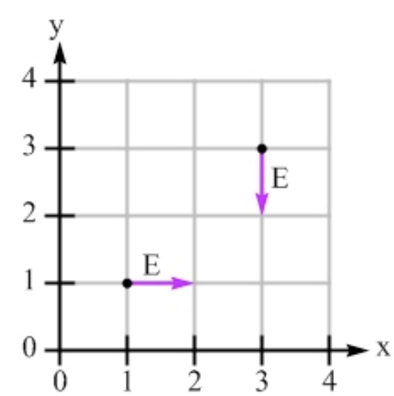


Figure 16.19: The electric field in this region is produced by a single point charge. The location of the point charge is not shown. For Exercise 6.

7. In a particular uniform electric field, the electric field lines are directed to the right. You draw a diagram to reflect this field, showing a number of equally spaced parallel arrows, separated by 1 cm, that are directed to the right. What would be the spacing between the arrows on your field-line diagram if the field was reduced in magnitude by a factor of 2?

8. You want to sketch a field-line pattern for a situation involving two point charges separated by some distance. One charge has a magnitude of $+3Q$ while the other has a magnitude of $-Q$. (a) If you draw 15 lines emerging from the $+3Q$ charge, how many should you draw ending on the $-Q$ charge? (b) Where do the remaining lines go? (c) At a point quite far from the two charges, the electric field looks like the electric field from a single point charge. What is the charge of this single point charge?

9. As shown in Figure 16.20, a positive test charge experiences a net force directed right when it is placed exactly halfway between a ball of charge $+Q$ and a second ball of unknown charge. (a) What is the direction of the electric field at the point where the test charge is? (b) What, if anything, can you conclude about the sign and/or magnitude of the charge on the second ball?

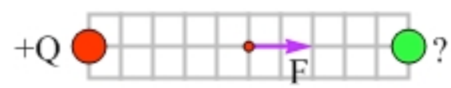


Figure 16.20: A positive test charge is located halfway between a ball of charge $+Q$ and a second ball of unknown charge. For Exercise 9.

10. As shown in Figure 16.21, a positive test charge experiences a net force directed right when the test charge is placed twice as far from a ball of unknown charge as it is from a ball of charge $+Q$. (a) What is the direction of the electric field at the point where the test charge is? (b) What, if anything, can you conclude about the sign and/or magnitude of the charge on the second ball?

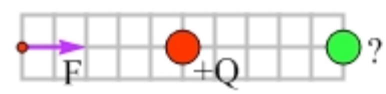


Figure 16.21: A ball of charge $+Q$ is located halfway between a positive test charge and a second ball of unknown charge. For Exercise 10.

11. Figure 16.23 shows three charged balls, which are equally spaced along a line. Each ball has a non-zero charge, but the signs of the charges on balls 1 and 3 are not shown. Ball 2 has a negative charge. The figure also shows the net force acting on each ball, because of its interaction with the other two balls. Assume that the only forces acting are electrostatic forces. (a) Ball 1 experiences no net force. What, if anything, does this tell us about the sign and magnitude of the charge on ball 3? Explain. (b) The net force on ball 2 is directed to the left. What, if anything, does this tell us about the sign and magnitude of the charge on ball 1? Explain. (c) Rank the balls, from largest to smallest, based on the magnitude of the charge on them.

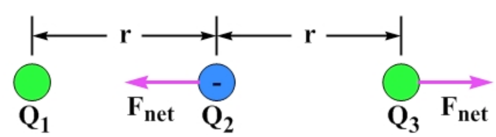


Figure 16.22: Three charged balls are equally spaced along a line. The sign of the charge on ball 2 is negative, but the signs of the charges on the other two balls are not shown. The net force on each ball is also shown – ball 1 experiences no net force due to its electrostatic interaction with the other two balls. For Exercise 11.

12. Three balls, with charges of $+q$, $+2q$, and $+3q$, are arranged so there is one ball at each corner of an equilateral triangle. Rank the balls based on the magnitude of the net electrostatic force they experience, from largest to smallest.

13. Five balls, two of charge $+q$ and three of charge $-2q$, are arranged as shown in Figure 16.23. What is the magnitude and direction of the net electrostatic force on the ball of charge $+q$ that is located at the origin?

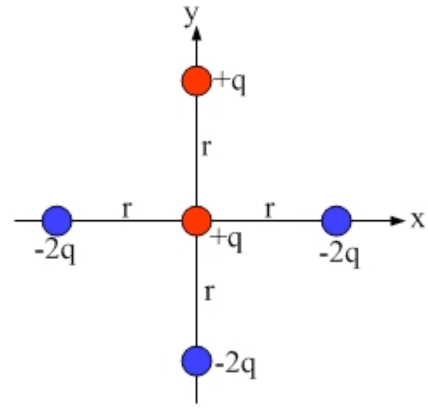


Figure 16.23: An arrangement of five charged balls, for Exercise 13.

14. Three charged balls are placed so that each is at a different corner of a square, as shown in Figure 16.24. Balls 1 and 3 both have positive charges, but the sign of the charge on ball 2 is not shown. The figure also shows the net force acting on each of the balls – the only forces that matter here are those associated with the interactions between the charges. (a) What, if anything, does the direction of the net force acting on ball 2 tell us about the sign of the charge on ball 2? Explain. (b) What, if anything, does the direction of the net force acting on ball 2 tell us about how the magnitude of the charge on ball 1 compares to the magnitude of the charge on ball 3? Explain. (c) What, if anything, does the direction of the net force acting on ball 3 tell us about how the magnitude of the charge on ball 1 compares to the magnitude of the charge on ball 2? Explain. (d) Rank the balls, from largest to smallest, based on the magnitude of the charge on them.

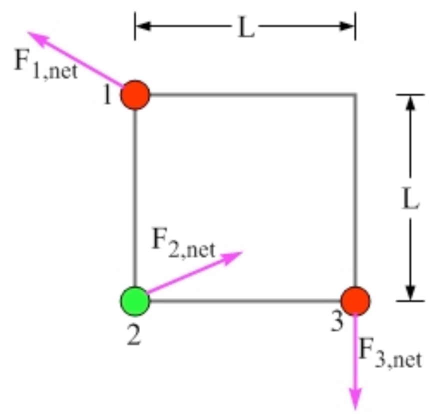


Figure 16.24: An arrangement of three charged balls, for Exercise 14. The arrows represent the net electrostatic force acting on each ball.

Exercises 15 – 20 deal with Coulomb's Law. Treat all charged balls as point charges.

15. Two point charges, one with a charge of $+Q$ and the other with a charge of $+16Q$, are placed on the x-axis. The $+Q$ charge is located at $x = +6a$, and experiences a force of magnitude kQ^2/a^2 because of its electrostatic interaction with the second charge. Where is the second point charge located? State all possible solutions.

16. Two small identical conducting balls have different amounts of charge on them. Initially, when they are separated by 75 cm, one ball exerts an attractive force of 1.50 N on the second ball. The balls are then touched together briefly, and then again separated by 75 cm. Now, both balls have a positive charge, and the force that one ball exerts on the other is a repulsive force of 1.10 N. What was the charge on the two balls originally?

17. Two charged balls are placed on the x-axis, as shown in Figure 16.25. The first ball has a charge $+q$ and is located at the origin, while the second ball has a charge $-4q$ and is located at $x = +4a$. A third ball, with a charge of $+2q$, is then brought in and placed somewhere on the x-axis. Assume that each ball is influenced only by the other two balls, and neglect gravitational interactions. (a) Could the third ball be placed so that all three balls simultaneously experience no net force due to the other two? (b) Could the third ball be placed so that at least one of the three balls experiences no net force due to the other two? Briefly justify your answers.

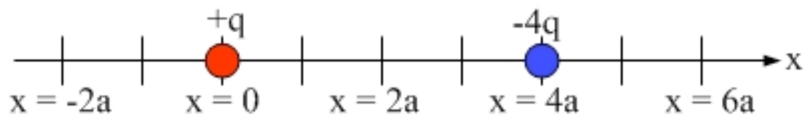


Figure 16.25: Two charged balls on the *x*-axis. For Exercises 17 – 19.

18. Return to the situation described in Exercise 17, and find all the possible locations where the third ball could be placed so that at least one of the three balls experiences no net force due to the other two.

19. Two charged balls are placed on the *x*-axis, as shown in Figure 16.25. The first ball has a charge $+q$ and is located at the origin, while the second ball has a charge $-4q$ and is located at $x = +4a$. Could a third ball, with an appropriate charge, be brought in and placed somewhere on the *x*-axis so that all three balls simultaneously experience no net force due to the other two? If so, find the charge and location of the third ball.

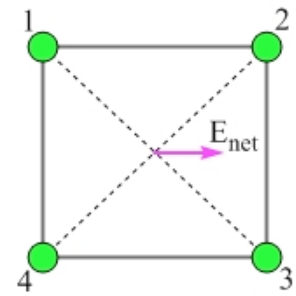
20. Three balls, each with the same magnitude charge, are arranged so there is one ball at each corner of an equilateral triangle. Each side of the triangle is exactly 1 meter long. (a) If each ball experiences a net force of 8.00×10^{-6} N because of the other two balls, what is the charge of each ball? (b) Must the sign of the charge on each ball be the same, or could the charge on one ball be opposite to that of the charge on the other two balls? Explain.

Exercises 21 – 31 deal with electric field. Treat all charged balls as point charges.

21. An electron with an initial velocity of 1500 m/s directed straight up is in a uniform electric field of 200 N/C that is also directed straight up. (a) The electron is near the surface of the Earth. Is it reasonable to neglect the influence of gravity in this situation? Justify your answer. (b) How long does it take for the electron to come instantaneously to rest? (c) How far does the electron travel in this time?

22. An electron with an initial velocity of 7.5×10^5 m/s directed horizontally is in a uniform electric field of 400 N/C that is directed straight up. The electron starts 2.0 m above a flat floor. (a) How long does it take the electron to reach the floor? (b) How far does the electron travel horizontally in this time? (c) What is the speed of the electron as it runs into the floor?

23. A single point charge is located at an unknown point on the *x*-axis. There are no other charged objects nearby. You measure the electric field at the origin to be 600 N/C in the positive *x*-direction, while the electric field on the *x*-axis at $x = +4.0$ m is 5400 N/C in the negative *x*-direction. What is the sign and magnitude of the point charge, and where is it located?



24. The net electric field at the center of a square is directed to the right, as shown in Figure 16.26. This net field is the vector sum of electric fields from four point charges, which are located so that there is one point charge at each corner of the square. The charges have identical magnitudes, but may be positive or negative. Which are positive and which are negative? Is there more than one possible answer?

Figure 16.26: Four point charges are placed so that there is one charge at each corner of a square. The charges all have the same magnitude, but they may have different signs. The net electric field at the center of the square, due to these four charges, is directed right. For Exercise 24.

25. A ball of with a charge of $+6q$ is placed on the x-axis at $x = -2a$. There is a second ball of unknown charge at $x = +a$. If the net electric field at the origin due to the two balls has a magnitude of $\frac{kq}{a^2}$, what is the charge of the second ball? Find all possible solutions.

26. Repeat the previous problem, but now the net electric field at the origin has a magnitude of $\frac{3kq}{a^2}$.

27. A ball with a charge of $-2q$ is placed on the x-axis at $x = -a$. There is a second ball with a charge of $+q$ that is placed on the x-axis at an unknown location. If the net electric field at the origin due to the two balls has a magnitude of $\frac{6kq}{a^2}$, what is the location of the second ball? Find all possible solutions.

28. Three balls, with charges of $+4q$, $-2q$, and $-q$, are equally spaced along a line. The spacing between the balls is r. We can arrange the balls in three different ways, as shown in Figure 16.27. In each case the balls are in an isolated region of space very far from anything else. (a) In which case does the ball with the charge of $+4q$ experience a larger-magnitude net force? Give a qualitative argument. (b) Calculate the magnitude and direction of the net force experienced by the $+4q$ charge in each case.

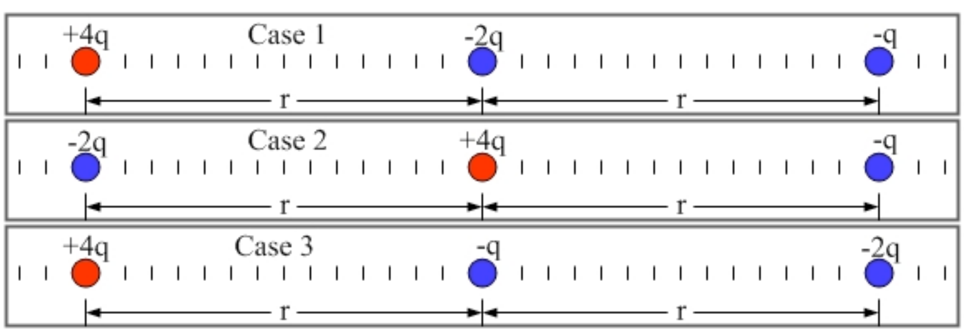


Figure 16.27: Three different arrangements of three balls of charge $+4q$, $-2q$, and $-q$ placed on a line with a distance r between neighboring balls. For Exercises 28 – 31.

29. Return to the situation described in Exercise 28, and shown in Figure 16.27. (a) Duplicate the diagram, and then draw in two force vectors on each ball in each case, to represent the force each ball experiences due to the other two balls. Figure 16.4 shows an example of this process. (b) Rank the three cases, from largest to smallest, based on the magnitude of the net force exerted on the ball in the middle of the set of three balls.

30. Return to the situation described in Exercise 28, and shown in Figure 16.27. Which ball experiences the largest-magnitude net force in (a) Case 1, (b) Case 2, and (c) Case 3? Calculate the magnitude and direction of the force applied to the ball that is experiencing the largest magnitude force in (d) Case 1, (e) Case 2, and (f) Case 3.

31. Consider the situation shown in case 3 in Figure 16.27. Each charged ball experiences a net force because of the other two balls – if you did the previous problem you would have calculated the three different net forces already. (a) If you add these three net forces as vectors, what do you get? Why? (b) Would you get the same result in all similar situations, including cases 1 and 2 in Figure 16.27? Why or why not?

Exercises 32 – 36 deal with test charges. Treat all charged balls as point charges.

32. As shown in Figure 16.28 (a), a positive test charge placed exactly halfway between a ball of charge $+Q$ and a second ball of unknown charge experiences a net force directed right. When the second ball is removed from the situation, as in Figure 16.28 (b), the force experienced by the test charge increases by a factor of 3/2. What is the sign and magnitude of the charge on the second ball in Figure 16.28 (a)?

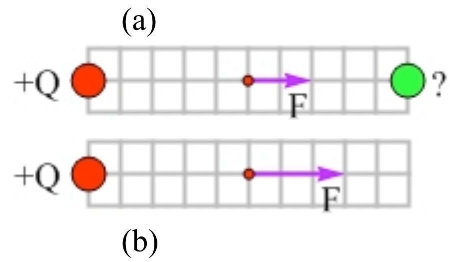


Figure 16.28: When the second ball shown in (a) is removed, as in (b), the force on the test charge increases by a factor of 3/2. For Exercise 32.

33. Figure 16.29 shows the net force experienced by a positive test charge located at the center of the diagram. The force comes from two nearby charged balls, one with a charge of $+Q$ and one with an unknown charge. (a) What is the sign of the charge on the second ball? (b) Is the magnitude of the charge on the second ball more than, less than, or equal to Q? (c) Find the sign and magnitude of the charge on the second ball.

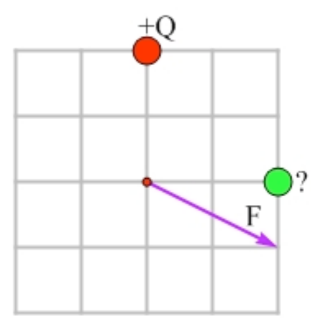


Figure 16.29: The two charged balls produce a net force directed down and to the right, as shown, on the test charge at the center of the diagram. For Exercise 33.

34. Figure 16.30 shows the net force experienced by a positive test charge located at the center of the diagram. The force comes from two nearby charged balls, one with a charge of $+Q$ and one with an unknown charge. (a) What is the sign of the charge on the second ball? (b) Is the magnitude of the charge on the second ball more than, less than, or equal to Q? (c) Find the sign and magnitude of the charge on the second ball.

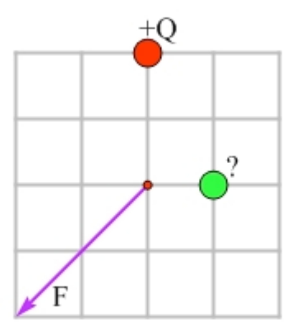


Figure 16.30: The two charged balls produce a net force at a 45° angle directed down and to the left, as shown, on the test charge at the center of the diagram. For Exercise 34.

35. Figure 16.31 shows the net force experienced by a positive test charge located at the center of the diagram. The force comes from two nearby charged balls, one with a charge of $+Q$ and one with an unknown charge. What is the sign and magnitude of the charge on the second ball?

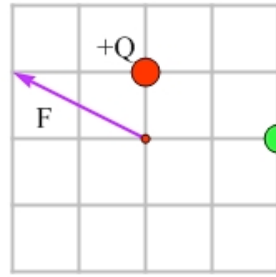


Figure 16.31: The two charged balls produce a net force directed up and to the left, as shown, on the test charge at the center of the diagram. For Exercise 35.

36. Two identical test charges are located at different positions, as shown in Figure 16.32. The test charges experience forces of the same magnitude, and in the directions shown. Could these forces be produced by a single nearby point charge? If so, state where that point charge would be and what you know about it. If not, explain why not.

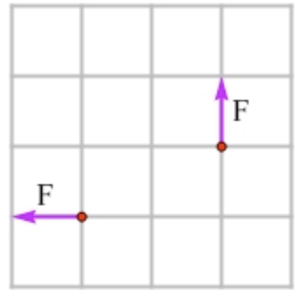


Figure 16.32: Two identical positive test charges experience the forces shown in the diagram. For Exercise 36.

General problems and conceptual questions. Treat all charged balls as point charges.

37. Benjamin Franklin made significant scientific contributions to our understanding of electric charge. Do some research on these contributions, and write two or three paragraphs describing them.

38. The SI unit of charge, the coulomb, is named after Charles-Augustin de Coulomb. Do some research on Coulomb (the scientist) and write a short biographical sketch of him.

39. A photocopier relies on the basic principles of charge. Do some research on how a photocopier works, and write a step-by-step explanation of the photocopying process.

40. At the laundromat, you put your silk pajamas in the dryer with your woolen sweater. When you take them out again, you find they are stuck together, because of static cling. Explain why this happens.

41. What is the speed of an electron in the ground state of a hydrogen atom? See Example 16.3A for relevant data, and use the Bohr model of the hydrogen atom, in which the electron follows a circular orbit around the proton.

42. Two small identical conducting balls have different amounts of charge on them. When they are first separated by 35 cm, one ball exerts a force with a magnitude of 4.50 N on the second ball. The balls are then touched together briefly, and then again separated by 35 cm. Now the force that one ball exerts on the other has a magnitude of 7.50 N. What was the charge on the two balls originally? Is there more than one possible solution?

43. Two identical balls each have a charge of -2.5×10^{-6} C. The balls hang from identical strings that are at 8.0° from the vertical because of the repulsive force between the charged balls. The balls are separated by a distance of 10 cm, as shown in Figure 16.33. What is the mass of each ball?

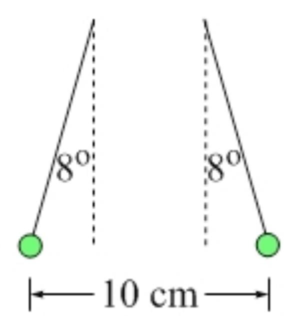


Figure 16.33: Two identical charged balls hang from strings, for Exercise 43.

44. Three balls, with charges of $+q$, $-2q$, and $+3q$, are arranged so there is one ball at each corner of an equilateral triangle. Each side of the triangle is exactly 2 meters long. (a) Find the magnitude of the net electrostatic force acting on the ball of charge $+3q$. (b) What is the magnitude of the electric field at the center of the triangle?

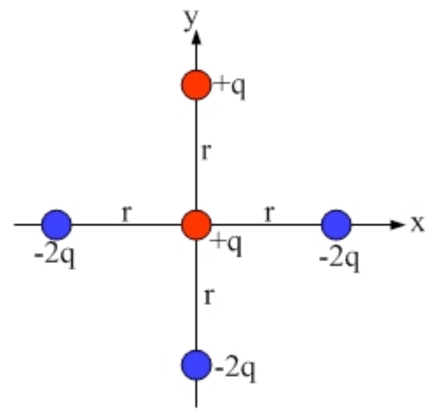


Figure 16.34: An arrangement of five charged balls, for Exercise 45.

45. (a) Referring to Figure 16.34, which of the two balls of charge $+q$ experiences the largest net electrostatic force? Justify your answer. (b) What is the magnitude of the net electrostatic force experienced by the three different balls of charge $-2q$?

46. A ball of charge $+3q$ is placed on the x-axis at $x = -a$. There is a second ball with an unknown charge that is placed on the x-axis at an unknown location. If the electrostatic force the second ball exerts on the first ball has a magnitude of $\frac{kq^2}{2a^2}$ and the net electric field at $x = 0$ due to these balls is $\frac{69kq}{25a^2}$ in the positive x direction, what is the charge and location of the second ball? Find all possible solutions.

47. Consider the three cases shown in Figure16.35. Rank these cases, from largest to smallest, based on the (a) magnitude of the electrostatic force experienced by the ball of charge $-q$; (b) magnitude of the electric field at the origin.

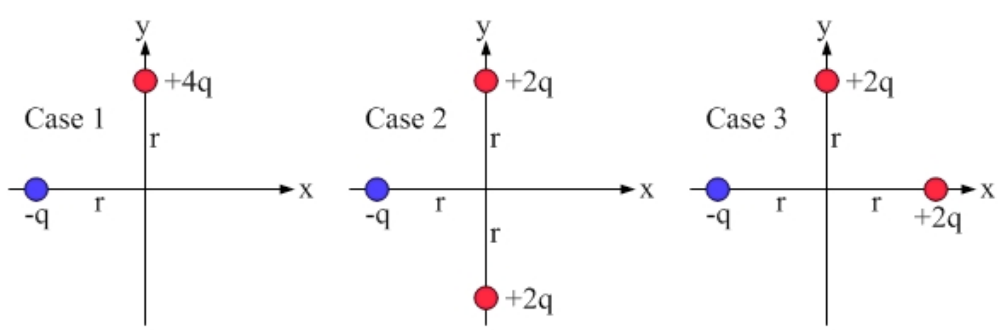


Figure 16.35: Three different configurations of charged objects, for Exercises 47 – 49.

48. Consider the three cases shown in Figure 16.35. Determine the magnitude and direction of the electrostatic force experienced by the ball of charge $-q$ in (a) case1; (b) case 2; (c) case 3.

49. Consider the three cases shown in Figure 16.35. Determine the magnitude and direction of the electric field at the origin in (a) case1; (b) case 2; (c) case 3.

50. Four small charged balls are arranged at the corners of a square that measures L on each side, as shown in Figure 16.36. (a) Which ball experiences the largest-magnitude force due to the other three balls? (b) What is the direction of the net force acting on the ball with the charge of $-4q$? (c) If you doubled the length of each side of the square, so neighboring charges were separated by a distance of $2L$ instead, what would happen to the magnitude of the force experienced by each charge?

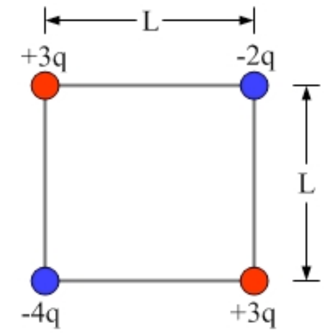


Figure 16.36: Four charged balls at the corners of a square, for Exercises 50 – 53.

51. Four small charged balls are arranged at the corners of a square that measures L on each side, as shown in Figure 16.36. To what value can you adjust the charge on the ball of charge $+3q$ in the lower right corner so that the ball of charge $+3q$ in the upper left corner experiences (a) a net force that points directly toward the ball of charge $-4q$, or (b) a net force that points directly away from the ball of charge $-2q$? (c) Determine the magnitude of the net force (in terms of k, q, and L) acting on the $+3q$ charge in the upper left corner in these two situations.

52. Four small charged balls are arranged at the corners of a square that measures L on each side, as shown in Figure 16.36. (a) If you adjust the charge on the ball with the $-4q$ charge at the lower left, could you bring the net force acting on the ball with the $-2q$ charge to zero? (b) If so, calculate the sign and magnitude of the charge on the ball in the lower left corner that would be required. If not, explain why not.

53. Four small charged balls are arranged at the corners of a square that measures L on each side, as shown in Figure 16.36. (a) Calculate the magnitude and direction of the electric field at the center of the square. (b) Could you change the amount of charge on one of the balls to produce a net electric field at the center that is directed horizontally to the left? If so, which ball would you change the charge of and what would you change it to? If not, explain why not.

54. A ball with a weight of 10 N hangs down from a string that will break if its tension is greater than or equal to 25 N. The ball has a charge of $+5.0\times10^{-6}$ C. You want to break the string by introducing a uniform electric field. What is the magnitude and direction of the minimum electric field required to cause the string to break?

55. A small charged ball with a weight of 10 N hangs from a string. When the ball is placed in a uniform electric field of 800 V/m directed left, the string makes a 40° angle with the vertical, as shown in Figure 16.37. What is the sign and magnitude of the charge on the ball?

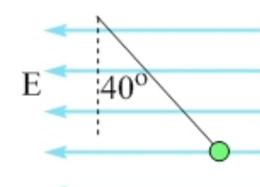


Figure 16.37: The equilibrium position of a ball in a uniform electric field directed left, for Exercise 55.

56. Return to Example 16.3B, in which we calculated the magnitude and direction of the net force exerted on the $-q$ charge by the other two charges. Now determine the magnitude and direction of the net force exerted on (a) the $+2q$ charge, and (b) the $-3q$ charge.

57. Return to the situation of Example 16.3B. Determine the magnitude and direction of the net electric field at (a) the center of the square, and (b) the unoccupied corner.

58. Three charged balls are placed in a line, as shown in Figure 16.38. Ball 1, which has an unknown charge and sign, is a distance 2*r* to the left of charge 2. Ball 2 is positive, with a charge of +*Q*. Ball 3 has an unknown non-zero charge and sign, and is a distance *r* to the right of ball 2. Ball 3 feels no net electrostatic force because of the other two balls. (a) Is there enough information given here to find the sign of the charge on ball 1? If so, what is the sign? (b) Can we find the magnitude of the charge on ball 1? If so, what is it? (c) Can we find the sign of the charge on ball 3? If so, what is the sign? (d) Can we find the magnitude of the charge on ball 3? If so, what is it?

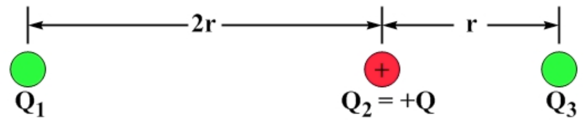


Figure 16.38: Three charges in a line. Only the sign and magnitude of charge 2 are known, although we also know that charge 3 is in equilibrium. For Exercise 58.

59. A single point charge is located at an unknown point on the *x*-axis. There are no other charged objects nearby. You measure the electric field at $x = +2.0$ m to be 6000 N/C, directed in the $+x$ direction, while the field at $x = +5.0$ m has a magnitude of 1500 N/C. What is the sign and magnitude of the point charge? State all possible answers.

60. In Example 16.6A we found one point on the line passing through two unequal charges at which the net electric field is zero. Are there any such points that are off this line, a finite distance from the charges? Use one or more diagrams to support your answer.

61. Consider the field-line diagram shown in Figure 16.39. The arrows show field lines emerging from charge 1, on the left, and ending at charge 2, on the right. (a) What is the sign of each of these charges? (b) If the charge on charge 1 has a magnitude of 10 μC, what is the charge on charge 2?

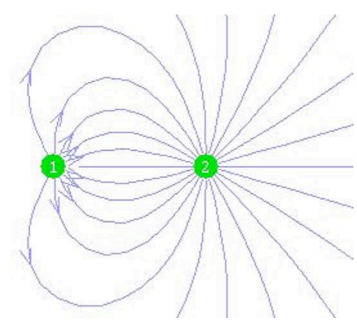


Figure 16.39: A field-line pattern near two charged objects, for Exercise 61.

62. One point charge is located at the origin, and has a charge of +5.0 μC. A second point charge is located at x = +2.0 m, and has a charge of –9.0 μC. (a) Analyze the situation qualitatively to determine approximate locations of any points where the net electric field due to these two point charges is zero. (b) Determine the location of all such points.

63. Repeat Exercise 62, except now the second point charge has a charge of +18.0 μC.

64. A charge of unknown sign and magnitude is located halfway between a small ball with a charge of +*Q* and a positive test charge. The test charge experiences a net force directed right, as shown in Figure 16.40. (a) What, if anything, can you conclude about the sign and/or magnitude of the unknown charge? (b) If you moved the test charge to the point halfway between the +*Q* charge and the unknown charge, in which direction would the force be on the test charge? (c) You return the test charge to the position shown in Figure 16.41. You then observe that when you shift the position of the unknown charge a little to the right, the force experienced by the test charge decreases in magnitude a little. What, if anything, can you conclude about the sign and/or magnitude of the unknown charge?

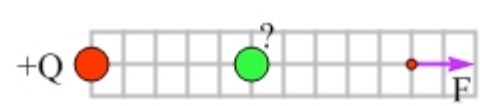


Figure 16.40: A charge of unknown sign and magnitude is located halfway between a small ball of charge +*Q* and a positive test charge. For Exercise 64.

65. One of the safest places to be in a lightning storm is inside a car, as long as the car is made of metal. Even if lightning strikes the car you should be safe inside. Explain why this is.

66. (a) Sketch a field-line pattern for a situation in which there is a uniform electric field directed straight down. (b) Re-draw the pattern for when a neutral metal sphere is placed into the field. Draw the sphere large enough that it covers a region on the diagram where at least 5 field lines pass through on your original diagram.

67. Figure 16.41 shows possible equilibrium distributions of charge on a hollow, thick-walled metal sphere that has a net charge of $-Q$. Which is most correct, assuming there are no other charged objects in the vicinity?

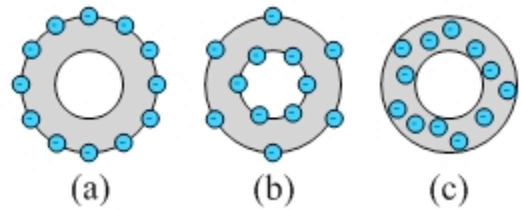


Figure 16.41: Possible equilibrium distributions of charge on a hollow, thick-walled metal sphere that has a net charge of $-Q$. In (a) the charge is spread uniformly over the outer surface; in (b) half the charge is distributed over the outer surface and half is on the inner surface; and in (c) the charge is randomly distributed throughout the bulk of the sphere. For Exercise 67.

68. Three students are having a conversation. Explain what you think is correct about what they say, and what you think is incorrect. In particular, how would you respond to Brenda's questions in the last statement?

Brenda: So, the question says that we have two objects, one with a +5Q charge and the other with a +Q charge, and it asks us for which one exerts a larger magnitude force on the other. Well, that's the +5Q object, right – it exerts 5 times as much force as the other one.

Paul: Let's think about Coulomb's law – it does say that when you increase one of the charges that the force goes up.

Lauren: Thinking about Coulomb's law makes sense, except that, in Coulomb's law, the force is proportional to the product of the two charges. You can apply it to each charge, and you get the same answer. So, I think the forces are the same.

Paul: That's consistent with Newton's third law, too – the objects have to exert equal and opposite forces on one another. That sounds right.

Brenda: That just doesn't make sense to me – shouldn't the bigger charge exert more force? I kind of got Newton's third law when we were talking about colliding carts a few months ago, but how can it can apply for things that don't even touch each other, like these little charges?