Answers to selected problems from Essential Physics, Chapter 16

1. This answer is not likely to be correct. Charge is quantized in units of *e*, which has a value of 1.60×10^{-19} C. Thus, we expect values of charge to be greater than or equal to *e*, not a small fraction of *e*, which is what we have in this case.

3. (a) Yes. The simplest way is to have them all start with equal charges. Another one of the many ways is to have A and B start with a total charge of +10*Q*, (such as +2*Q* on A and +8*Q* on B), and have C have a charge of +5*Q*, half of the total charge on A and B together. They would all end up with a charge of +5*Q*. (b) No, you can't have all three with different charges. B and C, which touch last, would end up with the same charge as one another. (c) Based on (b), if one sphere has a different sign it must be A. It can be done. One of the many ways is to start with –8*Q* on A, no charge on B, and +8*Q* on C. At the end, A has +2*Q* and B and C each have –*Q*.

5. (a) Yes, the force on B is doubled. (b) This also doubles the force. (c) This increases the force by a factor of 4. (d) This also increases the force by a factor of 4.

9. (a) to the right (b) It could be negative – if so, we have no information about the magnitude of the charge. It could also be positive, but if it is its magnitude must be less than *Q*.

11. (a) Ball 3 has a positive charge, with a magnitude equal to four times that of the magnitude of the charge on ball 2. Ball 1 has a non-zero charge, so it can only experience no net force when the force on it from ball 2 is exactly balanced by that on ball 3. To have these two forces point in opposite directions requires that the charge on ball 3 be opposite in sign to that on ball 2. To have the magnitudes of the two forces acting on ball 1 be equal, ball 3 must have a larger magnitude charge than ball 2, because ball 3 is farther away. We know that ball 3 is twice as far from ball 1 as ball 2 is, and, in Coulomb's law, that factor of 2 in the distance gets squared to a factor of 4 in the denominator. To make up for this factor of 4 in the denominator, there must be a factor of 4 in the numerator – this is what we get if ball 3 has a charge that has a magnitude four times that of ball 2. (b) Ball 1 has a positive charge, and it must be larger in magnitude than that of ball 3. Ball 2 is attracted to ball 3, because these two charges have opposite signs, so to have a net force on ball 2 that is directed to the left, ball 2 must be attracted to ball 1 (therefore, ball 1 is positive) with a larger force than that applied by ball 3 (thus, the charge on ball 1 is larger than that on ball 3). (c) 1 > 3 > 2.

13. $3kq^2/r^2$, in the negative *y*-direction.

15. There are two solutions. The second charge is located either at $x = +2a$ or at $x = +10a$.

17. (a) You can't set up a situation in which all three balls experience no net force. (b) You can have one of them feel no net force, however. For instance, to have the +*q* charge feel no net force, place the +2*q* charge between the +*q* and –4*q* charges (to the left of the

$-4q$ charge*)*, in just the right spot that the force it applies to the +q charge is balanced by that from the $-4q$ charge. On the other hand, for the $-4q$ charge to experience no net force, the $+2q$ charge has to be placed at just the right distance to the right of the $-4q$ charge.

21. (a) The acceleration because of the electric field is found from $ma = qE$, so $a = qE/m$, which has a value of about 3.5×10^{13} m/s, directed straight down. This is many orders of magnitude larger than the acceleration due to gravity, so it is quite reasonable to neglect the influence of gravity. (b) 4.3×10^{-11} s (c) 3.2×10^{-8} m

23. There is only one possible solution. There is a charge of -6.0×10^{-7} C at $x = +3$ m.

25. Two possible solutions. The unknown charge is either $+0.5q$ or $+2.5q$.

27. Two possible solutions. The unknown location is either at $x = +a/2$ or at $x = -\frac{a}{\sqrt{8}}$.

31. (a) The three net forces add up to zero. This is because we are really adding up three pairs of equal-and-opposite forces, which cancel. (b) Yes, we would always get this result, because we would always be adding up pairs of equal-and-opposite forces.

33. (a) negative (b) more than (c) $-2Q$.

35. This situation is not possible. The unknown charge, if it was positive, would exert a force to the left on the positive test charge. The original charge would exert a downward force on the test charge, however, and the unknown charge could not exert a force on the test charge so that the net force on the test charge had an upward component.

41. 2.2×10^{6} m/s

43. 4.08 kg

45. (a) The $+q$ charge at the origin experiences a larger net force than the $+q$ charge on the positive y-axis. In both cases, there is significant cancellation between the individual forces, but the $+q$ charge at the origin has the advantage of being closer, on average, to the charges exerting forces on it, and the two charges on the y-axis exert forces that are in the same direction. (b) The $-2q$ charge on the $-y$ axis experiences a net force of $(0.328)\frac{kq^2}{r^2}$ straight down. The $-2q$ charge on the $-x$ axis experiences a net force of $(4.26)\frac{kq^2}{r^2}$ at an angle of 84.4 degrees above the negative x-direction. The $-2q$ charge on the $+x$ axis experiences a net force of $(4.26)\frac{kq^2}{r^2}$ at an angle of 84.4° above the positive x-direction.

47. (a) 1 > 2 > 3 (b) 1 > 3 > 2

49. (a) $\sqrt{17}\frac{kq}{r^2}$ at an angle of 76° below the negative x-axis (b) $\frac{kq}{r^2}$ to the left

(c) $\sqrt{13}\frac{kq}{r^2}$ at an angle of 33.7° below the negative x-axis

51. (a) $+4\sqrt{2}\,q$ (b) $+8\sqrt{2}\,q$ (c) $\frac{6kq}{L^2}$ in both cases

53. (a) $\frac{4kq}{L^2}$ toward the lower left corner of the square (b) Either make the charge at the bottom right $+5q$, or make the charge at the upper left $+q$.

55. –0.010 C

57. (a) $\frac{4\sqrt{2}\,kq}{L^2}$ straight up (b) $(2.31)\frac{kq}{L^2}$ at an angle of 7.3° below the negative x-axis

59. There are two possible solutions. One solution is $+6 \times 10^{-6}$ C, located at $x = -1.0$ m, or the charge can be -6.67×10^{-7} C, located at $x = +3.0$ m.

61. (a) Charge 1 is positive and charge 2 is negative (b) Approximately 22 μC

63. (a) There is one location where the net field is zero, in between the two charges, and closer to the smaller charge. (b) The location is at $x = 0.69$ m.

67. Picture (a)