15. SSM **REASONING** The potential of each charge q at a distance r away is given by Equation 19.6 as $V = kq/r$. By applying this expression to each charge, we will be able to find the desired ratio, because the distances are given for each charge.

SOLUTION According to Equation 19.6, the potentials of each charge are

$$V_A = \frac{kq_A}{r_A} \quad \text{and} \quad V_B = \frac{kq_B}{r_B}$$

Since we know that $V_A = V_B$, it follows that

$$\frac{kq_A}{r_A} = \frac{kq_B}{r_B} \quad \text{or} \quad \frac{q_B}{q_A} = \frac{r_B}{r_A} = \frac{0.43\text{ m}}{0.18\text{ m}} = \boxed{2.4}$$

16. **REASONING** The electric potential energy EPE of the third charge q_3 is given by $\text{EPE} = q_3 V_{\text{Total}}$ (see Equation 19.3), where V_{Total} is the total potential at the point where the third charge is placed. The total potential at either of the empty corners is the sum of the individual potentials created by each of the charges. The individual potential created by a point charge q is $V = kq/r$ (Equation 19.6), where r is the distance between the charge and the empty corner.

SOLUTION We begin by noting that each side of the square has a length L, so that the diagonal has a length of $\sqrt{2}L$, according to the Pythagorean theorem. Using Equation 19.6, we can express the total potential at corners A and B as follows:

$$V_{\text{Total},A} = \frac{kq_2}{L} + \frac{kq_1}{\sqrt{2}L} \quad \text{and} \quad V_{\text{Total,B}} = \frac{kq_1}{L} + \frac{kq_2}{\sqrt{2}L}$$

Using Equation 19.3, we find that the electric potential energy of the third charge at each corner is:

$$\text{EPE}_A = q_3 V_{\text{Total},A} = q_3\left(\frac{kq_2}{L} + \frac{kq_1}{\sqrt{2}L}\right) = \frac{q_3 k}{L}\left(q_2 + \frac{q_1}{\sqrt{2}}\right)$$

$$= \frac{(-6.0\times10^{-9}\text{ C})(8.99\times10^{9}\text{ N}\cdot\text{m}^2/\text{C}^2)}{0.25\text{ m}}\left(+4.0\times10^{-9}\text{ C} + \frac{+1.5\times10^{-9}\text{ C}}{\sqrt{2}}\right)$$

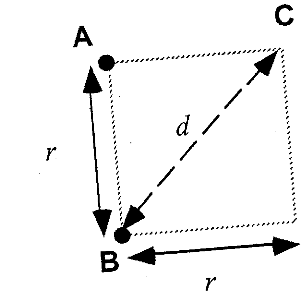
$$= \boxed{-1.1\times10^{-6}\text{ J}}$$

$$\text{EPE}_B = q_3 V_{\text{Total},B} = q_3\left(\frac{kq_1}{L} + \frac{kq_2}{\sqrt{2}L}\right) = \frac{q_3 k}{L}\left(q_1 + \frac{q_2}{\sqrt{2}}\right)$$

$$= \frac{(-6.0\times10^{-9}\text{ C})(8.99\times10^{9}\text{ N}\cdot\text{m}^2/\text{C}^2)}{0.25\text{ m}}\left(+1.5\times10^{-9}\text{ C} + \frac{+4.0\times10^{-9}\text{ C}}{\sqrt{2}}\right)$$

$$= \boxed{-0.93\times10^{-6}\text{ J}}$$

SSM WWW **REASONING** Initially, suppose that one charge is at C and the other charge is held fixed at B. The charge at C is then moved to position A. According to Equation 19.4, the work W_{CA} done by the electric force as the charge moves from C to A is $W_{CA} = q(V_C - V_A)$, where, from Equation 19.6, $V_C = kq/d$ and $V_A = kq/r$. From the figure at the right we see that $d = \sqrt{r^2 + r^2} = \sqrt{2}r$. Therefore, we find that

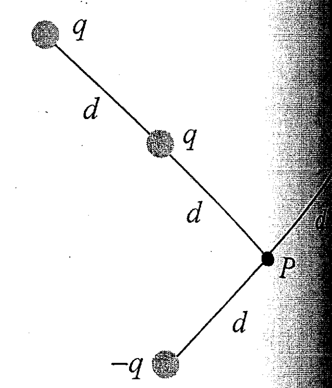


$$W_{CA} = q\left(\frac{kq}{\sqrt{2}r} - \frac{kq}{r}\right) = \frac{kq^2}{r}\left(\frac{1}{\sqrt{2}} - 1\right)$$

SOLUTION Substituting values, we obtain

$$W_{CA} = \frac{(8.99\times10^{9}\text{ N}\cdot\text{m}^2/\text{C}^2)(3.0\times10^{-6}\text{ C})^2}{0.500\text{ m}}\left(\frac{1}{\sqrt{2}} - 1\right) = \boxed{-4.7\times10^{-2}\text{ J}}$$

18. ***REASONING*** The electric potential at a distance r from a point charge q is given by Equation 19.6 as $V = kq/r$. The total electric potential at location P due to the four point charges is the algebraic sum of the individual potentials.



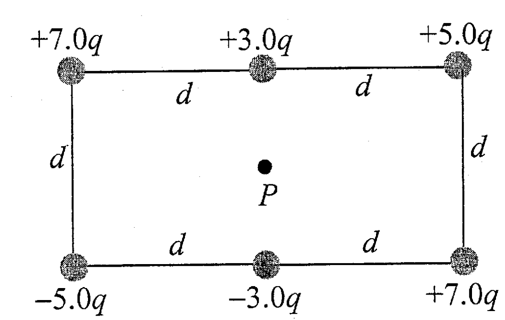
SOLUTION The total electric potential at P is (see the drawing)

$$V = \frac{k(-q)}{d} + \frac{k(+q)}{2d} + \frac{k(+q)}{d} + \frac{k(-q)}{d} = \frac{-kq}{2d}$$

Substituting in the numbers gives

$$V = \frac{-kq}{2d} = \frac{-\left(8.99\times10^{9}\ \frac{\mathrm{N\cdot m^2}}{\mathrm{C^2}}\right)\left(2.0\times10^{-6}\ \mathrm{C}\right)}{2(0.96\ \mathrm{m})} = \boxed{-9.4\times10^{3}\ \mathrm{V}}$$

19. ***REASONING*** The electric potential at a distance r from a point charge q is given by Equation 19.6 as $V = kq/r$. The total electric potential at location P due to the six point charges is the algebraic sum of the individual potentials.



SOLUTION Starting at the upper left corner of the rectangle, we proceed clockwise and add up the six contributions to the total electric potential at P (see the drawing):

$$V = \frac{k(+7.0q)}{\sqrt{d^2+\left(\frac{d}{2}\right)^2}} + \frac{k(+3.0q)}{\frac{d}{2}} + \frac{k(+5.0q)}{\sqrt{d^2+\left(\frac{d}{2}\right)^2}} + \frac{k(+7.0q)}{\sqrt{d^2+\left(\frac{d}{2}\right)^2}} + \frac{k(-3.0q)}{\frac{d}{2}} + \frac{k(-5.0q)}{\sqrt{d^2+\left(\frac{d}{2}\right)^2}}$$

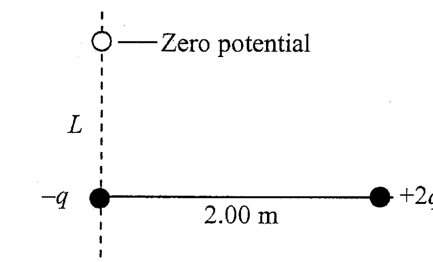
$$= \frac{k(+14.0q)}{\sqrt{d^2+\left(\frac{d}{2}\right)^2}}$$

Substituting $q = 9.0\times10^{-6}$ C and $d = 0.13$ m gives

$$\frac{k(+14.0q)}{\sqrt{d^2+\left(\frac{d}{2}\right)^2}} = \frac{\left(8.99\times10^{9}\ \frac{\mathrm{N\cdot m^2}}{\mathrm{C^2}}\right)(+14.0)\left(9.0\times10^{-6}\ \mathrm{C}\right)}{\sqrt{(0.13\ \mathrm{m})^2+\left(\frac{0.13\ \mathrm{m}}{2}\right)^2}} = \boxed{+7.8\times10^{6}\ \mathrm{V}}$$

REASONING The potential from the positive charge is positive, while the potential from the negative charge is negative at the spot in question. The magnitude of the positive potential must be equal to the magnitude of the negative potential. Only then will the algebraic sum of the two potentials give zero for the total potential.

The drawing shows the arrangement of the charges. The two charges and the spot in question form a right triangle. Therefore, the distance between the positive charge and the zero-potential spot is the hypotenuse of the right triangle and, according to the Pythagorean theorem, is greater than L.



There are two spots on the dashed line where the total potential is zero. One spot is shown in the drawing. The other spot is on the dashed line at a distance L below the negative charge.

SOLUTION We begin by noting that the distance between the positive charge $+2q$ and the zero-potential spot is given by the Pythagorean theorem as $\sqrt{L^2+(2.00\ \mathrm{m})^2}$. With this in mind and using $V = kq/r$ (Equation 19.6), we write the total potential at the spot in question as follows:

$$V_{\mathrm{Total}} = \frac{k(-q)}{L} + \frac{k(+2q)}{\sqrt{L^2+(2.00\ \mathrm{m})^2}} = 0 \quad \text{or} \quad \frac{1}{L} = \frac{+2}{\sqrt{L^2+(2.00\ \mathrm{m})^2}}$$

Squaring both sides of this result gives

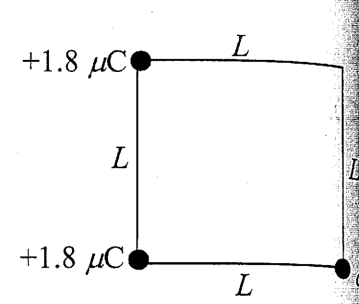
$$\frac{1}{L^2} = \frac{4}{L^2+(2.00\ \mathrm{m})^2} \quad \text{or} \quad L^2+(2.00\ \mathrm{m})^2 = 4L^2$$

Solving for L, we obtain

$$3L^2 = (2.00\ \mathrm{m})^2 \quad \text{or} \quad L = \frac{2.00\ \mathrm{m}}{\sqrt{3}} = \boxed{1.15\ \mathrm{m}}$$

21. ***REASONING*** The potential V created by a point charge q at a spot that is located at a distance r is given by Equation 19.6 as $V = \frac{kq}{r}$, where q can be either a positive or negative quantity, depending on the nature of the charge. We will apply this expression to obtain the potential created at the empty corner by each of the three charges fixed to the square. The total potential at the empty corner is the sum of these three contributions. Setting this sum equal to zero will allow us to obtain the unknown charge.

SOLUTION The drawing at the right shows the three charges fixed to the corners of the square. The length of each side of the square is denoted by L. Note that the distance between the unknown charge q and the empty corner is L. Note also that the distance between one of the 1.8-μC charges and the empty corner is $r = L$, but that the distance between the other 1.8-μC charge and the empty corner is $r = \sqrt{L^2 + L^2} = \sqrt{2}L$, according to the Pythagorean theorem.



Using Equation 19.6 to express the potential created by the unknown charge q and by each of the 1.8-μC charges, we find that the total potential at the empty corner is

$$V_{\text{total}} = \frac{kq}{L} + \frac{k\left(+1.8\times10^{-6}\text{ C}\right)}{L} + \frac{k\left(+1.8\times10^{-6}\text{ C}\right)}{\sqrt{2}L} = 0$$

In this result the constant k and the length L can be eliminated algebraically, leading to the following result for q:

$$q + 1.8\times10^{-6}\text{ C} + \frac{1.8\times10^{-6}\text{ C}}{\sqrt{2}} = 0 \quad \text{or} \quad q = \left(-1.8\times10^{-6}\text{ C}\right)\left(1 + \frac{1}{\sqrt{2}}\right) = \boxed{-3.1\times10^{-6}\text{ C}}$$

22. ***REASONING*** The radius R of the circle is the distance between each charge and the center of the circle, where we know the total electric potential V. The total electric potential is the sum of the contributions V_1, V_2, and V_3 made by the three charges. We will use $V = \frac{kq}{r}$ (Equation 19.6), where k = 8.99×10^9 N·m^2/C^2 and $r = R$ to determine each of the three contributions to the total electric potential. Summing the contributions and equating the result to V = - 2100 V, we will obtain the radius R of the circle.

SOLUTION From $V = \frac{kq}{r}$ (Equation 19.6), the total potential V at the center of the circle is

$$V = V_1 + V_2 + V_3 = \frac{kq_1}{R} + \frac{kq_2}{R} + \frac{kq_3}{R} = \frac{k\left(q_1 + q_2 + q_3\right)}{R} \qquad (1)$$

Solving Equation (1) for R, we find that

$$R = \frac{k\left(q_1 + q_2 + q_3\right)}{V}$$

$$= \frac{\left(8.99\times10^{9}\text{ N}\cdot\text{m}^2/\text{C}^2\right)\left(-5.8\times10^{-9}\text{ C} - 9.0\times10^{-9}\text{ C} + 7.3\times10^{-9}\text{ C}\right)}{-2100\text{ V}} = \boxed{0.032\text{ m}}$$

23. $\boxed{\text{SSM}}$ ***REASONING*** The only force acting on the moving charge is the conservative electric force. Therefore, the sum of the kinetic energy KE and the electric potential energy EPE is the same at points A and B:

$$\tfrac{1}{2}mv_{\text{A}}^2 + \text{EPE}_{\text{A}} = \tfrac{1}{2}mv_{\text{B}}^2 + \text{EPE}_{\text{B}}$$

Since the particle comes to rest at B, $v_{\text{B}} = 0$. Combining Equations 19.3 and 19.6, we have

$$\text{EPE}_{\text{A}} = qV_{\text{A}} = q\left(\frac{kq_1}{d}\right)$$

and

$$\text{EPE}_{\text{B}} = qV_{\text{B}} = q\left(\frac{kq_1}{r}\right)$$

where d is the initial distance between the fixed charge and the moving charged particle, and r is the distance between the charged particles after the moving charge has stopped. Therefore, the expression for the conservation of energy becomes

$$\tfrac{1}{2}mv_{\text{A}}^2 + \frac{kqq_1}{d} = \frac{kqq_1}{r}$$

This expression can be solved for r. Once r is known, the distance that the charged particle moves can be determined.

SOLUTION Solving the expression above for r gives

$$r=\frac{kqq_1}{\frac{1}{2}mv_A^2+\frac{kqq_1}{d}}$$

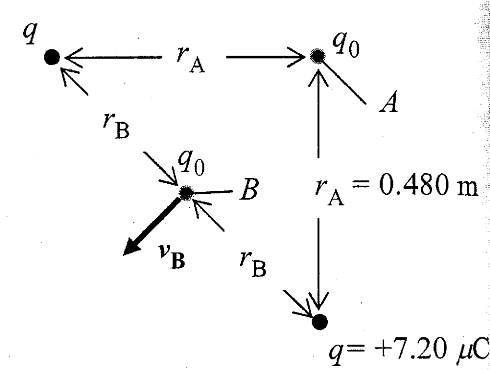
$$=\frac{(8.99\times10^9\,\mathrm{N\cdot m^2/C^2})(-8.00\times10^{-6}\,\mathrm{C})(-3.00\times10^{-6}\,\mathrm{C})}{\frac{1}{2}(7.20\times10^{-3}\,\mathrm{kg})(65.0\ \mathrm{m/s})^2+\frac{(8.99\times10^9\,\mathrm{N\cdot m^2/C^2})(-8.00\times10^{-6}\,\mathrm{C})(-3.00\times10^{-6}\,\mathrm{C})}{0.0450\ \mathrm{m}}}$$

$$=0.0108\ \mathrm{m}$$

Therefore, the charge moves a distance of $0.0450\ \mathrm{m}-0.0108\ \mathrm{m}=\boxed{0.0342\ \mathrm{m}}$.

---

24. ***REASONING*** The speed v_B of the test charge at position B, the center of the square, is related to its kinetic energy by $\mathrm{KE}_B=\frac{1}{2}mv_B^2$ (Equation 6.2). No forces other than the conservative electric force act on the test charge, so the total mechanical energy of the test charge is conserved as it accelerates from its initial position A at one corner of the square to its final position B. There is no rotational motion and no elastic potential energy, and the test charge is at rest at position A, so the conservation of energy takes the following form:



$$\underbrace{\tfrac{1}{2}mv_B^2}_{\substack{\text{Kinetic}\\\text{energy}\\\text{at }B}}+\underbrace{\mathrm{EPE}_B}_{\substack{\text{Electric}\\\text{potential}\\\text{energy at }B}}=\underbrace{\tfrac{1}{2}m(0\ \mathrm{m/s})^2}_{\substack{\text{Kinetic}\\\text{energy at }A}}+\underbrace{\mathrm{EPE}_A}_{\substack{\text{Electric}\\\text{potential}\\\text{energy at }A}}\qquad\text{or}\qquad \tfrac{1}{2}mv_B^2+\mathrm{EPE}_B=\mathrm{EPE}_A \qquad (1)$$

In Equation (1), m is the mass of the test charge. At both position A and position B, the electric potential energy EPE of the test charge is determined by $\mathrm{EPE}=q_0V$ (Equation 19.3), where V is the total electric potential due to both of the charges q. We will use $V=\frac{kq}{r}$ (Equation 19.6), where $k=8.99\times10^9\,\mathrm{N{\cdot}m^2/C^2}$ to obtain the total electric potential at positions A and B.

SOLUTION At positions A and B, the total electric potential is the sum of the electric potentials due to the charges q. Since the charges are identical, and both are equidistant from positions A and B, the total potentials V_A and V_B are twice the potentials due to either charge alone. Therefore, from $V=\frac{kq}{r}$ (Equation 19.6), we have that

$$V_A=2\left(\frac{kq}{r_A}\right)=\frac{2kq}{r_A}\qquad\text{and}\qquad V_B=2\left(\frac{kq}{r_B}\right)=\frac{2kq}{r_B}\qquad(2)$$

In Equation (2), $r_A=0.480$ m is the length of one side of the square, and r_B is half the length of the diagonal $r_A\sqrt{2}$ of the square, so that $r_B=\frac{1}{2}\left(r_A\sqrt{2}\right)=\frac{1}{2}\sqrt{2}\,(0.480\ \mathrm{m})=0.339\ \mathrm{m}$. Substituting Equations (2) into $\mathrm{EPE}=q_0V$ (Equation 19.3) yields

$$\mathrm{EPE}_A=q_0V_A=q_0\left(\frac{2kq}{r_A}\right)=\frac{2kq_0q}{r_A}\qquad\text{and}\qquad \mathrm{EPE}_B=q_0V_B=q_0\left(\frac{2kq}{r_B}\right)=\frac{2kq_0q}{r_B}\qquad(3)$$

Substituting Equations (3) into Equation (1), we obtain

$$\tfrac{1}{2}mv_B^2+\frac{2kq_0q}{r_B}=\frac{2kq_0q}{r_A}\qquad(4)$$

Solving Equation (4) for v_B^2, we find that

$$\tfrac{1}{2}mv_B^2=\frac{2kq_0q}{r_A}-\frac{2kq_0q}{r_B}\qquad\text{or}\qquad \tfrac{1}{2}mv_B^2=2kq_0q\left(\frac{1}{r_A}-\frac{1}{r_B}\right)\qquad\text{or}\qquad v_B^2=\frac{4kqq_0}{m}\left(\frac{1}{r_A}-\frac{1}{r_B}\right)$$

Therefore, the speed of the test charge at the center of the square is

$$v_B=\sqrt{\frac{4kqq_0}{m}\left(\frac{1}{r_A}-\frac{1}{r_B}\right)}$$

$$=\sqrt{\frac{4\left(8.99\times10^9\ \mathrm{N\cdot m^2/C^2}\right)\left(7.20\times10^{-6}\ \mathrm{C}\right)\left(-2.40\times10^{-8}\ \mathrm{C}\right)}{\left(6.60\times10^{-8}\ \mathrm{kg}\right)}\left(\frac{1}{0.480\ \mathrm{m}}-\frac{1}{0.339\ \mathrm{m}}\right)}$$

$$=\boxed{290\ \mathrm{m/s}}$$

$$\text{EPE}_{\text{Total}}=\text{EPE}_1+\text{EPE}_2+\text{EPE}_3+\text{EPE}_4$$

$$=0\text{ J}+0.090\text{ J}+0.13\text{ J}+0.16\text{ J}=\boxed{0.38\text{ J}}$$

---

27. SSM ***REASONING*** Initially, the three charges are infinitely far apart. We will p... as in Example 8 by adding charges to the triangle, one at a time, and determining the e... potential energy at each step. According to Equation 19.3, the electric potential energ... is the product of the charge q and the electric potential V at the spot where the cha... placed, EPE = qV. The total electric potential energy of the group is the sum of the en... of each step in assembling the group.

SOLUTION Let the corners of the triangle be numbered clockwise as 1, 2 and 3, sta... with the top corner. When the first charge (q_1 = 8.00 μC) is placed at a corner 1, the ch... has no electric potential energy, $\text{EPE}_1 = 0$. This is because the electric potential V_1 pro... by the other two charges at corner 1 is zero, since they are infinitely far away.

Once the 8.00-μC charge is in place, the electric potential V_2 that it creates at corner 2 i...

$$V_2=\frac{kq_1}{r_{21}}$$

where r_{21} = 5.00 m is the distance between corners 1 and 2, and q_1 = 8.00 μC. Whe... 20.0-μC charge is placed at corner 2, its electric potential energy EPE_2 is

$$\text{EPE}_2=q_2V_2=q_2\left(\frac{kq_1}{r_{21}}\right)$$

$$=\left(20.0\times10^{-6}\text{ C}\right)\left[\frac{\left(8.99\times10^{9}\text{ N}\cdot\text{m}^2/\text{C}^2\right)\left(8.00\times10^{-6}\text{ C}\right)}{5.00\text{ m}}\right]=0.288\text{ J}$$

The electric potential V_3 at the remaining empty corner is the sum of the potentials ... the two charges that are already in place on corners 1 and 2:

$$V_3=\frac{kq_1}{r_{31}}+\frac{kq_2}{r_{32}}$$

where q_1 = 8.00 μC, r_{31} = 3.00 m, q_2 = 20.0 μC, and r_{32} = 4.00 m. When the third ... (q_3 = −15.0 μC) is placed at corner 3, its electric potential energy EPE_3 is

$$\text{EPE}_3=q_3V_3=q_3\left(\frac{kq_1}{r_{31}}+\frac{kq_2}{r_{32}}\right)=q_3k\left(\frac{q_1}{r_{31}}+\frac{q_2}{r_{32}}\right)$$

$$=\left(-15.0\times10^{-6}\text{ C}\right)\left(8.99\times10^{9}\text{ N}\cdot\text{m}^2/\text{C}^2\right)\left(\frac{8.00\times10^{-6}\text{ C}}{3.00\text{ m}}+\frac{20.0\times10^{-6}\text{ C}}{4.00\text{ m}}\right)=-1.034\text{ J}$$

...electric potential energy of the entire array is given by

$$\text{EPE}=\text{EPE}_1+\text{EPE}_2+\text{EPE}_3=0+0.288\text{ J}+(-1.034\text{ J})=\boxed{-0.746\text{ J}}$$

...***REASONING AND SOLUTION*** The electrical potential energy of the group of charges is

$$\text{EPE}=kq_1q_2/d+kq_1q_3/(2d)+kq_2q_3/d=0$$

$$q_1q_2+(1/2)q_1q_3+q_2q_3=0$$

a. If $q_1 = q_2 = q$, then

$$q+(1/2)q_3+q_3=0 \qquad \text{or} \qquad \boxed{q_3=-\tfrac{2}{3}q}$$

b. If $q_1 = q$ and $q_2 = -q$ then

$$-q+(1/2)q_3-q_3=0 \qquad \text{or} \qquad \boxed{q_3=-2q}$$

REASONING The only force acting on each particle is the conservative electric force. ...erefore, the total energy (kinetic energy plus electric potential energy) is conserved as the ...ticles move apart. In addition, the net external force acting on the system of two particles ...ro (the electric force that each particle exerts on the other is an internal force). Thus, the ...tal linear momentum of the system is also conserved. We will use the conservation of ...ergy and the conservation of linear momentum to find the final speed of each particle.

SOLUTION For two points, A and B, along the motion, the conservation of energy is

$$\underbrace{\tfrac{1}{2}mv_{1,A}^2+\tfrac{1}{2}mv_{2,A}^2}_{\substack{\text{Initial kinetic energy}\\ \text{of the two particles}}}+\underbrace{\frac{kq_1q_2}{r_A}}_{\substack{\text{Initial electric}\\ \text{potential energy}}}=\underbrace{\tfrac{1}{2}mv_{1,B}^2+\tfrac{1}{2}mv_{2,B}^2}_{\substack{\text{Final kinetic energy}\\ \text{of the two particles}}}+\underbrace{\frac{kq_1q_2}{r_B}}_{\substack{\text{Final electric}\\ \text{potential energy}}}$$

...tting $v_{1,A} = v_{2,A} = 0$ since the particles are initially at rest, and letting $r_B=\frac{1}{3}r_A$, the ...nservation of energy equation becomes

$$\tfrac{1}{2}mv_{1,B}^2 + \tfrac{1}{2}mv_{2,B}^2 = -\frac{2kq_1q_2}{r_A} \qquad (1)$$

This equation cannot be solved for $v_{1,B}$ because the final speed $v_{2,B}$ of the second particle is not known. To find this speed, we will use the conservation of linear momentum:

$$\underbrace{mv_{1,A} + mv_{2,A}}_{\text{Initial linear momentum}} = \underbrace{mv_{1,B} + mv_{2,B}}_{\text{Final linear momentum}}$$

Setting $v_{1,A} = v_{2,A} = 0$ and solving for $v_{2,B}$ gives $v_{2,B} = -v_{1,B}$. Substituting this result into Equation (1) and solving for $v_{1,B}$ yields

$$v_{1,B} = \sqrt{\frac{-2kq_1q_2}{mr_A}}$$

$$= \sqrt{\frac{-2\left(9.0\times10^{9}\ \mathrm{N\cdot m^2/C^2}\right)\left(+5.0\times10^{-6}\ \mathrm{C}\right)\left(-5.0\times10^{-6}\ \mathrm{C}\right)}{\left(6.0\times10^{-3}\ \mathrm{kg}\right)\left(0.80\ \mathrm{m}\right)}} = \boxed{9.7\ \mathrm{m/s}}$$

This is also the speed of $v_{2,B}$.

30. ***REASONING AND SOLUTION*** The information about the electric field requires that

$$k|q_2|/(1.00\ \mathrm{m})^2 = k|q_1|/(4.00\ \mathrm{m})^2 \quad \text{so} \quad |q_2| = (1/16.0)\ |q_1|$$

Since q_2 is negative and q_1 is positive, this result implies that

$$-q_2 = q_1/16.0 \qquad (1)$$

Let x be the distance of the zero-potential point from the negative charge and d be the separation between the charges. Then, the total potential is

$$kq_1/(d+x) + kq_2/x = 0$$

if the point is to the right of q_2 and

$$kq_1/(d-x) + kq_2/x = 0$$

if the point is between the charges and to the left of q_2. Using Equation (1) and solving for x in each case gives

$\boxed{x = 0.200\ \text{m to the right of the negative charge}}$

$\boxed{x = 0.176\ \text{m to the left of the negative charge}}$

31. ***REASONING*** The electric potential V at a distance r from a point charge q is $V = kq/r$ (Equation 19.6). The potential is the same at all points on a spherical surface whose distance from the charge is $r = kq/V$. We will use this relation to find the distance between the two equipotential surfaces.

SOLUTION The radial distance r_{75} from the charge to the 75.0-V equipotential surface is $r_{75} = kq/V_{75}$, and the distance to the 190-V equipotential surface is $r_{190} = kq/V_{190}$. The distance between these two surfaces is

$$r_{75} - r_{190} = \frac{kq}{V_{75}} - \frac{kq}{V_{190}} = kq\left(\frac{1}{V_{75}} - \frac{1}{V_{190}}\right)$$

$$= \left(8.99\times10^{9}\ \frac{\mathrm{N\cdot m^2}}{\mathrm{C^2}}\right)\left(+1.50\times10^{-8}\ \mathrm{C}\right)\left(\frac{1}{75.0\ \mathrm{V}} - \frac{1}{190\ \mathrm{V}}\right) = \boxed{1.1\ \mathrm{m}}$$

32. ***REASONING*** The equipotential surfaces that surround a point charge q are spherical. Each has a potential V that is given by $V = \frac{kq}{r}$ (Equation 19.6), where $k = 8.99 \times 10^9\ \mathrm{N\cdot m^2/C^2}$ and r is the radius of the sphere. Equation 19.6 can be solved for q, provided that we can obtain a value for the radius r. The radius can be found from the given surface area A, since the surface area of a sphere is $A = 4\pi r^2$.

SOLUTION Solving $V = \frac{kq}{r}$ (Equation 19.6) for q gives

$$q = \frac{Vr}{k}$$

Since the surface area of a sphere is $A = 4\pi r^2$, it follows that $r = \sqrt{\frac{A}{4\pi}}$. Substituting this result into the expression for q gives

$$q = \frac{Vr}{k} = \frac{V}{k}\sqrt{\frac{A}{4\pi}} = \frac{490\ \mathrm{V}}{8.99\times10^{9}\ \mathrm{N\cdot m^2/C^2}}\sqrt{\frac{1.1\ \mathrm{m^2}}{4\pi}} = \boxed{1.6\times10^{-8}\ \mathrm{C}}$$

39. SSM ***REASONING AND SOLUTION*** Let point A be on the x-axis where the potential is 515 V. Let point B be on the x-axis where the potential is 495 V. From Equation 19.7a the electric field is

$$E = -\frac{\Delta V}{\Delta s} = -\frac{V_B - V_A}{\Delta s} = -\frac{495\text{ V} - 515\text{ V}}{-2\left(6.0\times10^{-3}\text{ m}\right)} = -1.7\times10^{3}\text{ V/m}$$

The magnitude of the electric field is $\boxed{1.7\times10^{3}\text{ V/m}}$. Since the electric field is negative, it points to the $\boxed{\text{left}}$, from the high toward the low potential.

40. ***REASONING*** The outside force is the only nonconservative force acting on the particle. Therefore, the work W_{nc} done by the outside force changes the total mechanical energy $E = \text{KE} + \text{EPE}$ of the particle according to $W_{\text{nc}} = \Delta\text{KE} + \Delta\text{EPE}$ (Equation 6.7b), where $\Delta\text{KE} = \text{KE}_\text{B} - \text{KE}_\text{A}$ is the difference between the kinetic energy of the particle at equipotential surface B and that at equipotential surface A, and $\Delta\text{EPE} = \text{EPE}_\text{B} - \text{EPE}_\text{A}$ is the corresponding difference between the electric potential energies of the particle. The kinetic energy of the particle is found from its mass m and speed v via $\text{KE} = \frac{1}{2}mv^2$ (Equation 6.2):

$$\text{KE}_\text{A} = \tfrac{1}{2}mv_\text{A}^2 \qquad \text{and} \qquad \text{KE}_\text{B} = \tfrac{1}{2}mv_\text{B}^2 \tag{1}$$

The electric potential energy of the particle is given by $\text{EPE} = qV$ (Equation 19.3), where q is the charge of the particle, and V is the potential at an equipotential surface. Therefore, we have that

$$\text{EPE}_\text{A} = qV_\text{A} \qquad \text{and} \qquad \text{EPE}_\text{B} = qV_\text{B} \tag{2}$$

SOLUTION Substituting $\Delta\text{KE} = \text{KE}_\text{B} - \text{KE}_\text{A}$ and $\Delta\text{EPE} = \text{EPE}_\text{B} - \text{EPE}_\text{A}$ into the relation $W_{\text{nc}} = \Delta\text{KE} + \Delta\text{EPE}$ (Equation 6.7b), we obtain

$$W_{\text{nc}} = \Delta\text{KE} + \Delta\text{EPE} = \left(\text{KE}_\text{B} - \text{KE}_\text{A}\right) + \left(\text{EPE}_\text{B} - \text{EPE}_\text{A}\right) \tag{3}$$

Substituting Equations (1) and (2) into Equation (3) yields

$$W_{\text{nc}} = \left(\tfrac{1}{2}mv_\text{B}^2 - \tfrac{1}{2}mv_\text{A}^2\right) + \left(qV_\text{B} - qV_\text{A}\right) = \tfrac{1}{2}m\left(v_\text{B}^2 - v_\text{A}^2\right) + q\left(V_\text{B} - V_\text{A}\right)$$

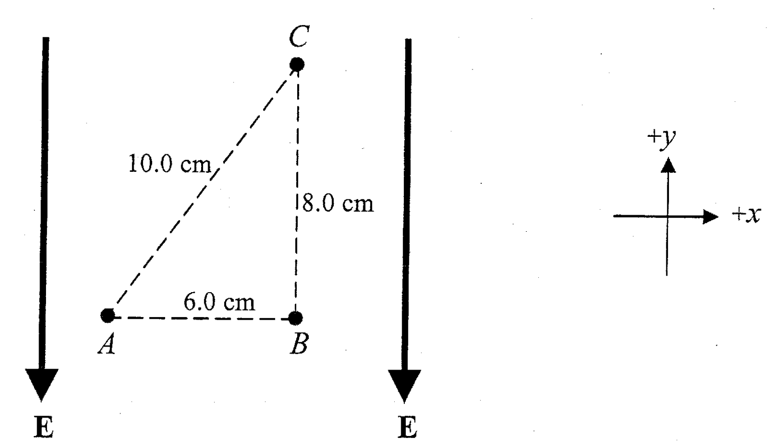
Therefore, the work done by the outside force in moving the particle from A to B is

$$W_{\text{nc}} = \tfrac{1}{2}\left(5.00\times10^{-2}\text{ kg}\right)\left[(3.00\text{ m/s})^2 - (2.00\text{ m/s})^2\right] + \left(4.00\times10^{-5}\text{ C}\right)(7850\text{ V} - 5650\text{ V})$$
$$= \boxed{0.213\text{ J}}$$

41. ***REASONING***
a. The potential difference $V_B - V_A$ between points A and B is related to the work W_{AB} done by the electric force when a charge q_0 moves from A to B; $V_B - V_A = -W_{AB}/q_0$ (Equation 19.4). Since the displacement from A to B is perpendicular to the electric force, no work is done, so $W_{AB} = 0$ J (see Section 6.1).

b. The potential difference $\Delta V = V_C - V_B$ between B and C is related to the electric field E and the displacement Δs by $\Delta V = -E\ \Delta s$ (Equation 19.7a). Since E and Δs are known, we can use this expression to find ΔV.

c. Since the electric force is a conservative force, it does not matter which path we take between points A and C to find the potential difference $V_A - V_C$. Therefore, we can retrace our steps in parts a and b to find this potential difference.



SOLUTION
a. As discussed in the ***Reasoning*** section, the displacement from A to B is perpendicular to the electric force, so no work is done. Thus the potential difference is

$$V_B - V_A = \frac{-W_{AB}}{q_0} = \frac{0\text{ J}}{q_0} = \boxed{0\text{ V}}$$

b. We have that $V_C - V_B = -E\ \Delta s$ (Equation 19.7a). Since the electric field points in the negative y direction, $E = -3600$ N/C. The displacement from B to C is positive, so $\Delta s = +0.080$ m. Thus, the potential difference is