12. ***REASONING*** The electric potential difference between the two points is $V_B - V_A = \frac{kq}{r_B} - \frac{kq}{r_A}$ (Equation 19.5). We can use this expression directly to calculate the electric potential difference.

SOLUTION According to Equation 19.5, the electric potential difference is

$$V_B - V_A = \frac{kq}{r_B} - \frac{kq}{r_A} = kq\left(\frac{1}{r_B} - \frac{1}{r_A}\right)$$

$$= \left(8.99\times10^9 \text{ N}\cdot\text{m}^2/\text{C}^2\right)\left(-2.1\times10^{-9}\text{ C}\right)\left(\frac{1}{0.50\text{ m}} - \frac{1}{0.25\text{ m}}\right) = \boxed{38\text{ V}}$$

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14. ***REASONING*** The potential at a distance r from a point charge q is given by Equation 19.6 as $V = kq/r$. Therefore, the potential difference between the locations B and A can be written as

$$V_B - V_A = \frac{kq}{r_B} - \frac{kq}{r_A}$$

We can use this relation to find the charge q.

SOLUTION Solving the equation above for q yields

$$q = \frac{V_B - V_A}{k\left(\dfrac{1}{r_B} - \dfrac{1}{r_A}\right)} = \frac{45.0\ \text{V}}{\left(8.99\times10^{9}\ \dfrac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\left(\dfrac{1}{4.00\ \text{m}} - \dfrac{1}{3.00\ \text{m}}\right)} = \boxed{-6.0\times10^{-8}\ \text{C}}$$

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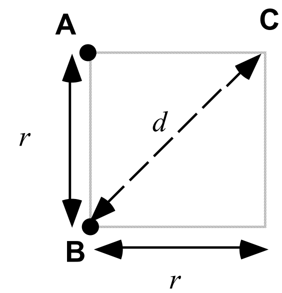
15. SSM WWW ***REASONING*** Initially, suppose that one charge is at C and the other charge is held fixed at B. The charge at C is then moved to position A. According to Equation 19.4, the work W_{CA} done by the electric force as the charge moves from *C* to *A* is $W_{CA} = q(V_C - V_A)$, where, from 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

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

---

17. ***REASONING AND SOLUTION*** Let the first spot where the potential is zero be a distance x to the left of the negative charge. Then,

$$\frac{k(2q)}{d-x} = \frac{kq}{x} \qquad or \qquad x = \boxed{\frac{d}{3}}$$

Let the second spot where the potential is zero be a distance x to the right of the negative charge. Then,

$$\frac{k(2q)}{d+x} = \frac{kq}{x} \qquad or \qquad x = \boxed{d}$$

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19. 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:

$$\tfrac{1}{2}mv_A^2 + \text{EPE}_A = \tfrac{1}{2}mv_B^2 + \text{EPE}_B$$

Since the particle comes to rest at B**,** $v_B = 0$. Combining Equations 19.3 and 19.6, we have

$$\text{EPE}_A = qV_A = q\left(\frac{kq_1}{d}\right)$$

and

$$\text{EPE}_B = qV_B = q\left(\frac{kq_1}{r}\right)$$

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

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

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

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

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

$$= 0.0108\text{ m}$$

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

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27. SSM ***REASONING*** The magnitude E of the electric field is given by Equation 19.7a (without the minus sign) as $E = \frac{\Delta V}{\Delta s}$, where ΔV is the potential difference between the two metal conductors of the spark plug, and Δs is the distance between the two conductors. We can use this relation to find ΔV.

SOLUTION The potential difference between the conductors is

$$\Delta V = E\Delta s = \left(4.7\times10^{7}\text{ V/m}\right)\left(0.75\times10^{-3}\text{ m}\right) = \boxed{3.5\times10^{4}\text{ V}}$$

29. ***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

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

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

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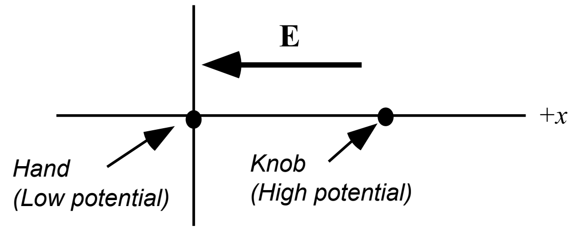
31. SSM WWW ***REASONING AND SOLUTION*** As described in the problem statement, the charges jump between your hand and a doorknob. If we assume that the electric field is uniform, Equation 19.7a applies, and we have



$$E = -\frac{\Delta V}{\Delta s} = -\frac{V_{\text{knob}} - V_{\text{hand}}}{\Delta s}$$

Therefore, solving for the potential difference between your hand and the doorknob, we have

$$V_{\text{knob}} - V_{\text{hand}} = -E\Delta s = -(-3.0\times10^{6}\text{ N/C})(3.0\times10^{-3}\text{ m}) = \boxed{+9.0\times10^{3}\text{ V}}$$

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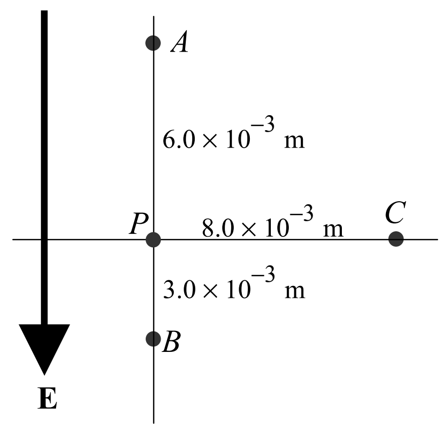
33. ***REASONING*** The drawing shows the electric field **E** and the three points, A, B, and C, in the vicinity of point P, which we take as the origin. We choose the upward direction as being positive. Thus, $E = -4.0 \times 10^3$ V/m, since the electric field points straight down. The electric potential at points A and B can be determined from Equation 19.7a as $\Delta V = -E\Delta s$, since E and Δs are known. Since the path from P to C is perpendicular to the electric field, no work is done in moving a charge along such a path. Thus, the potential difference between these two points is zero.



SOLUTION

a. The potential difference between points P and A is $V_A - V_P = -E\,\Delta s$. The potential at A is

$$V_A = V_P - E\,\Delta s = 155 \text{ V} - \left(-4.0\times10^3 \text{ V/m}\right)\left(6.0\times10^{-3} \text{ m}\right) = \boxed{179 \text{ V}}$$

b. The potential difference between points P and B is $V_B - V_P = -E\,\Delta s$. The potential at B is

$$V_B = V_P - E\,\Delta s = 155 \text{ V} - \left(-4.0\times10^3 \text{ V/m}\right)\left(-3.0\times10^{-3} \text{ m}\right) = \boxed{143 \text{ V}}$$

c. Since the path from P to C is perpendicular to the electric field and no work is done in moving a charge along such a path, it follows that $\Delta V = 0$ V. Therefore, $V_C = V_P = \boxed{155 \text{ V}}$.

36. ***REASONING AND SOLUTION*** The capacitance is given by

$$C = \frac{k\varepsilon_0 A}{d} = \frac{5\left(8.85\times10^{-12}\,\text{F/m}\right)\left(5\times10^{-6}\,\text{m}^2\right)}{1\times10^{-8}\,\text{m}} = \boxed{2\times10^{-8}\,\text{F}}$$

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37. SSM ***REASONING*** The charge that resides on the outer surface of the cell membrane is $q = CV$, according to Equation 19.8. Before we can use this expression, however, we must first determine the capacitance of the membrane. If we assume that the cell membrane behaves like a parallel plate capacitor filled with a dielectric, Equation 19.10 ($C = \kappa \varepsilon_0 A / d$) applies as well.

SOLUTION The capacitance of the cell membrane is

$$C = \frac{\kappa\varepsilon_0 A}{d} = \frac{(5.0)(8.85\times10^{-12}\ \text{F/m})(5.0\times10^{-9}\ \text{m}^2)}{1.0\times10^{-8}\,\text{m}} = 2.2\times10^{-11}\,\text{F}$$

a. The charge on the outer surface of the membrane is, therefore,

$$q = CV = (2.2\times10^{-11}\ \text{F})(60.0\times10^{-3}\ \text{V}) = \boxed{1.3\times10^{-12}\ \text{C}}$$

b. If the charge in part (a) is due to K^+ ions with charge $+e$ ($e = 1.6 \times 10^{-19}$ C), the number of ions present on the outer surface of the membrane is

$$\begin{matrix}\text{Number of} \\ \text{K}^+\ \text{ions}\end{matrix} = \frac{1.3\times10^{-12}\,\text{C}}{1.6\times10^{-19}\,\text{C}} = \boxed{8.1\times10^{6}}$$

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39. ***REASONING***

a. The energy used to produce the flash is stored in the capacitor as electrical energy. The energy stored depends on the capacitance C of the capacitor and the potential difference V between its plates; $\text{Energy} = \frac{1}{2}CV^2$ (Equation 19.11b).

b. The power of the flash is the energy consumed divided by the duration of the flash (see Equation 6.10b).

SOLUTION

a. The energy used to produce the flash is

$$\text{Energy} = \tfrac{1}{2}CV^2 = \tfrac{1}{2}\left(850\times10^{-6}\text{ F}\right)\left(280\text{ V}\right)^2 = \boxed{33\text{ J}}$$

b. The power developed by the flash is

$$P = \frac{\text{Energy}}{\text{Time}} = \frac{33\text{ J}}{3.9\times10^{-3}\text{s}} = \boxed{8500\text{ W}}$$

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40. ***REASONING AND SOLUTION*** The capacitance is $C = q_0/V_0 = q/V$. The new charge q is, therefore,

$$q = \frac{q_0 V}{V_0} = \frac{\left(5.3\times10^{-5}\,\text{C}\right)\left(9.0\text{ V}\right)}{6.0\text{ V}} = \boxed{8.0\times10^{-5}\,\text{C}}$$

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43. ***REASONING*** According to Equation 19.11b, the energy stored in a capacitor with a capacitance C and potential V across its plates is $\text{Energy} = \frac{1}{2}CV^2$. Once we determine how much energy is required to operate a 75-W light bulb for one minute, we can then use the expression for the energy to solve for V.

SOLUTION The energy stored in the capacitor, which is equal to the energy required to operate a 75-W bulb for one minute (= 60 s), is

$$\text{Energy} = Pt = (75\ \text{W})(60\ \text{s}) = 4500\ \text{J}$$

Therefore, solving Equation 19.11b for V, we have

$$V = \sqrt{\frac{2(\text{Energy})}{C}} = \sqrt{\frac{2(4500\ \text{J})}{3.3\ \text{F}}} = \boxed{52\ \text{V}}$$

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44. ***REASONING*** The charge q stored on the plates of a capacitor connected to a battery of voltage V is $q = CV$ (Equation 19.8). The capacitance C is $C = \frac{\kappa \varepsilon_0 A}{d}$ (Equation 19.10), where κ is the dielectric constant of the material between the plates, ε_0 is the permittivity of free space, A is the area of each plate, and d is the distance between the plates. Once the capacitor is charged and disconnected from the battery, there is no way for the charge on the plates to change. Therefore, as the distance between the plates is doubled, the charge q must remain constant. However, Equation 19.10 indicates that the capacitance is inversely proportional to the distance d, so the capacitance decreases as the distance increases. In Equation 19.8, as C decreases, the voltage V must increase in order that q remains constant. The voltage increases as a result of the work done in moving the plates farther apart. In solving this problem, we will apply Equations 19.8 and 19.10 to the capacitor twice, once with the smaller and once with the larger value of the distance between the plates.

SOLUTION Using $q = CV$ (Equation 19.8) and $C = \frac{\kappa \varepsilon_0 A}{d}$ (Equation 19.10), we can express the charge on the capacitor as follows:

$$q = CV = \left(\frac{\kappa \varepsilon_0 A}{d} \right) V = \frac{\varepsilon_0 A V}{d}$$

where we have made use of the fact that $\kappa = 1$, since the capacitor is empty. Applying this result to the capacitor with smaller and larger values of the distance d, we have

$$q = \frac{\varepsilon_0 A V_{\text{smaller}}}{d_{\text{smaller}}} \quad \text{and} \quad q = \frac{\varepsilon_0 A V_{\text{larger}}}{d_{\text{larger}}}$$

Since q is the same in each of these expressions, it follows that

$$\frac{\varepsilon_0 A V_{\text{smaller}}}{d_{\text{smaller}}} = \frac{\varepsilon_0 A V_{\text{larger}}}{d_{\text{larger}}} \quad \text{or} \quad \frac{V_{\text{smaller}}}{d_{\text{smaller}}} = \frac{V_{\text{larger}}}{d_{\text{larger}}}$$

Thus, we find that the voltage increases to a value of

$$V_{\text{larger}} = V_{\text{smaller}} \left(\frac{d_{\text{larger}}}{d_{\text{smaller}}} \right) = (9.0 \text{ V}) \left(\frac{2 d_{\text{smaller}}}{d_{\text{smaller}}} \right) = \boxed{18 \text{ V}}$$