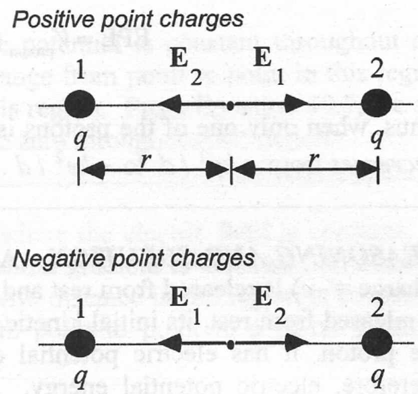
6. ***REASONING AND SOLUTION*** The electric field at a single location is zero. This does not necessarily mean that the electric potential at the same place is zero. According to Equation 19.7, $E = -\Delta V / \Delta s$. Therefore, the fact that **E** = 0 means that the potential gradient, $\Delta V / \Delta s$, is zero, and the potential difference does not change with distance. In other words, in the vicinity of a point where **E** is zero, the electric potential is constant, but not necessarily zero

To illustrate this fact, consider the situation of two identical point charges. The electric field at each location in the vicinity of the charges is the resultant of the electric field at that location due to each of the two charges. The magnitude of the field due to each charge is given by Equation 18.3: $E = kq / r^2$. At the point exactly halfway between the charges, along the line that joins them, r is the same for the field contribution from each charge; therefore, the magnitudes of the field contributions at this point are the same. Since the charges are identical, the directions of the field contributions at this point are in opposite directions. The following figure shows the situation for both positive and negative charges. The resultant of the two field contributions is zero. Thus, the electric field is zero exactly

halfway between the charges on the line that joins them. The electric potential at this point, however, is the algebraic sum of the potential at that point due to each individual charge. Therefore, the potential at the point exactly halfway between the charges is



$$V = \frac{kq}{r} + \frac{kq}{r} = \frac{2kq}{r}$$

which is clearly non-zero.

16. ***REASONING AND SOLUTION*** Since both particles are released from rest, their initial kinetic energies are zero. They both have electric potential energy by virtue of their respective positions in the electric field between the plates. Since the particles are oppositely charged, they move in opposite directions toward opposite plates of the capacitor. As they move toward the plates, the particles gain kinetic energy and lose potential energy. Using $(\text{EPE})_0$ and $(\text{EPE})_f$ to denote the initial and final electric potential energies of the particle, respectively, we find from energy conservation that

$$(\text{EPE})_0 = \tfrac{1}{2} m_{\text{particle}} v_f^2 + (\text{EPE})_f$$

The final speed of each particle is given by

$$v_f = \sqrt{\frac{2\left[(\text{EPE})_0 - (\text{EPE})_f\right]}{m_{\text{particle}}}}$$

Since both particles travel through the same distance between the plates of the capacitor, the change in the electric potential energy is the same for both particles. Since the mass of the electron is smaller than the mass of the proton, the final speed of the electron will be greater than that of the proton. Therefore, the electron travels faster than the proton as the particles move toward the respective plates. The electron, therefore, strikes the capacitor plate first.

20. ***REASONING*** It will not matter in what order the group is assembled. For convenience, we will assemble the group from one end of the line to the other. The potential energy of each charge added to the group will be determined and the four values added together to get the total. At each step, the electric potential energy of an added charge q_0 is given by Equation 19.3 as $\text{EPE} = q_0 V_{\text{Total}}$, where V_{Total} is the potential at the point where the added charge is placed. The potential V_{Total} will be determined by adding together the contributions from the charges previously put in position, each according to Equation 19.6 ($V = kq/r$).

SOLUTION The first charge added to the group has no electric potential energy, since the spot where it goes has a total potential of $V_{\text{Total}} = 0$ J, there being no charges in the vicinity to create it:

$$\text{EPE}_1 = q_0 V_{\text{Total}} = \left(2.0\times10^{-6}\ \text{C}\right)\left(0\ \text{V}\right) = 0\ \text{J}$$

The second charge experiences a total potential that is created by the first charge:

$$V_{\text{Total}} = \frac{kq}{r} = \frac{\left(8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(+2.0\times10^{-6}\ \text{C}\right)}{0.40\ \text{m}} = 4.5\times10^{4}\ \text{V}$$

$$\text{EPE}_2 = q_0 V_{\text{Total}} = \left(2.0\times10^{-6}\ \text{C}\right)\left(4.5\times10^{4}\ \text{V}\right) = 0.090\ \text{J}$$

The third charge experiences a total potential that is created by the first and the second charges:

$$V_{\text{Total}} = \frac{\left(8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(+2.0\times10^{-6}\ \text{C}\right)}{0.80\ \text{m}} + \frac{\left(8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(+2.0\times10^{-6}\ \text{C}\right)}{0.40\ \text{m}} = 6.7\times10^{4}\ \text{V}$$

$$\text{EPE}_3 = q_0 V_{\text{Total}} = \left(2.0\times10^{-6}\ \text{C}\right)\left(6.7\times10^{4}\ \text{V}\right) = 0.13\ \text{J}$$

The fourth charge experiences a total potential that is created by the first, second, and third charges:

$$V_{\text{Total}} = \frac{\left(8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(+2.0\times10^{-6}\ \text{C}\right)}{1.2\ \text{m}} + \frac{\left(8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(+2.0\times10^{-6}\ \text{C}\right)}{0.80\ \text{m}} + \frac{\left(8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(+2.0\times10^{-6}\ \text{C}\right)}{0.40\ \text{m}} = 8.2\times10^{4}\ \text{V}$$

$$\text{EPE}_4 = q_0 V_{\text{Total}} = \left(2.0\times10^{-6}\ \text{C}\right)\left(8.2\times10^{4}\ \text{V}\right) = 0.16\ \text{J}$$

The total electric potential energy of the group is

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

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

28. ***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

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

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

34. ***REASONING*** The electric field E that exists between two points in space is, according to Equation 19.7, proportional to the electric potential difference ΔV between the points divided by the distance Δx between them: $E = -\Delta V/\Delta x$.

SOLUTION

a. The electric field in the region from A to B is

$$E = -\frac{\Delta V}{\Delta x} = -\frac{5.0\text{ V} - 5.0\text{ V}}{0.20\text{ m} - 0\text{ m}} = \boxed{0\text{ V/m}}$$

b. The electric field in the region from B to C is

$$E = -\frac{\Delta V}{\Delta x} = -\frac{3.0\text{ V} - 5.0\text{ V}}{0.40\text{ m} - 0.20\text{ m}} = \boxed{1.0 \times 10^{1}\text{ V/m}}$$

c. The electric field in the region from C to D is

$$E = -\frac{\Delta V}{\Delta x} = -\frac{1.0\text{ V} - 3.0\text{ V}}{0.80\text{ m} - 0.40\text{ m}} = \boxed{5.0\text{ V/m}}$$

46. ***REASONING AND SOLUTION*** The charge on the empty capacitor is $q_0 = C_0V_0$. With the dielectric in place, the charge remains the same. However, the new capacitance is $C = \kappa C_0$ and the new voltage is V. Thus,

$$q_0 = CV = \kappa C_0\, V = C_0V_0$$

Solving for the new voltage yields

$$V = V_0/\kappa = (12.0\text{ V})/\,2.8 = 4.3\text{ V}$$

The potential difference is $12.0 - 4.3 = \boxed{7.7\text{ V}}$. The change in potential is a $\boxed{\text{decrease}}$.