1. If two points are at the same potential, does this mean that no work is done in moving a test charge from one point to the other? Does this imply that no force must be exerted? Explain.

1. Not necessarily. If two points are at the same potential, then no *net* work is done in moving a charge from one point to the other, but work (both positive and negative) could be done at different parts of the path. No. It is possible that positive work was done over one part of the path, and negative work done over another part of the path, so that these two contributions to the net work sum to zero. In this case, a non-zero force would have to be exerted over both parts of the path.

6. If $V = 0$ at a point in space, must $\vec{\mathbf{E}} = 0$? If $\vec{\mathbf{E}} = 0$ at some point, must $V = 0$ at that point? Explain. Give examples for each.

6. No. Electric potential is the *potential energy* per unit charge at a point in space and electric field is the *electric force* per unit charge at a point in space. If one of these quantities is zero, the other is not necessarily zero. For example, the point exactly between two charges with equal magnitudes and opposite signs will have a zero electric potential because the contributions from the two charges will be equal in magnitude and opposite in sign. (Net electric potential is a *scalar* sum.) This point will not have a zero electric field, however, because the electric field contributions will be in the same direction (towards the negative and away from the positive) and so will add. (Net electric field is a *vector* sum.) As another example, consider the point exactly between two equal positive point charges. The electric potential will be positive since it is the sum of two positive numbers, but the electric field will be zero since the field contributions from the two charges will be equal in magnitude but opposite in direction.

14. If you know V at a point in space, can you calculate $\vec{\mathbf{E}}$ at that point? If you know $\vec{\mathbf{E}}$ at a point can you calculate V at that point? If not, what else must be known in each case?

14. No. You cannot calculate electric potential knowing only electric field at a point and you cannot calculate electric field knowing only electric potential at a point. As an example, consider the uniform field between two charged, conducting plates. If the potential difference between the plates is known, then the distance between the plates must also be known in order to calculate the field. If the field between the plates is known, then the distance to a point of interest between the plates must also be known in order to calculate the potential there. In general, to find V, you must know E and be able to integrate it. To find E, you must know V and be able to take its derivative. Thus you need E or V in the region around the point, not just at the point, in order to be able to find the other variable.

19. Is the electric potential energy of two unlike charges positive or negative? What about two like charges? What is the significance of the sign of the potential energy in each case?

19. The electric potential energy of two unlike charges is negative. The electric potential energy of two like charges is positive. In the case of unlike charges, work must be done to separate the charges. In the case of like charges, work must be done to move the charges together.

3. (I) An electron acquires 5.25×10^{-16} J of kinetic energy when it is accelerated by an electric field from plate A to plate B. What is the potential difference between the plates, and which plate is at the higher potential?

3. The kinetic energy gained by the electron is the work done by the electric force. Use Eq. 23-2b to calculate the potential difference.

$$V_{ba} = -\frac{W_{ba}}{q} = -\frac{5.25\times10^{-16}\,\text{J}}{(-1.60\times10^{-19}\,\text{C})} = \boxed{3280\,\text{V}}$$

The electron moves from low potential to high potential, so $\boxed{\text{plate B}}$ is at the higher potential.

11. (II) A uniform electric field $\vec{\mathbf{E}} = -4.20\,\text{N/C}\,\hat{\mathbf{i}}$ points in the negative x direction as shown in Fig. 23–25. The x and y coordinates of points A, B, and C are given on the diagram (in meters). Determine the differences in potential (*a*) V_{BA}, (*b*) V_{CB}, and (*c*) V_{CA}.

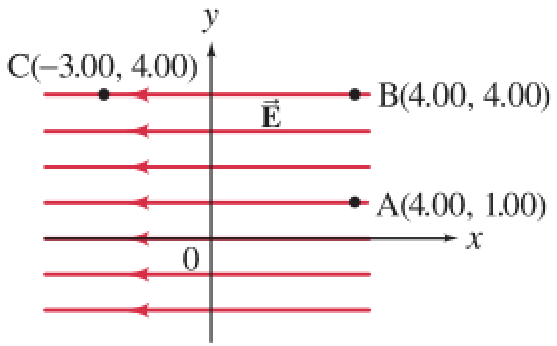

FIGURE 23–25
Problem 11.

11. Since the field is uniform, we may apply Eq. 23-4b. Note that the electric field always points from high potential to low potential.

(*a*) $\boxed{V_{BA} = 0}$. The distance between the two points is exactly perpendicular to the field lines.

(*b*) $V_{CB} = V_C - V_B = (-4.20\,\text{N/C})(7.00\,\text{m}) = \boxed{-29.4\,\text{V}}$

(*c*) $V_{CA} = V_C - V_A = V_C - V_B + V_B - V_A = V_{CB} + V_{BA} = -29.4\,\text{V} + 0 = \boxed{-29.4\,\text{V}}$

17. (II) Suppose the end of your finger is charged. (*a*) Estimate the breakdown voltage in air for your finger. (*b*) About what surface charge density would have to be on your finger at this voltage?

17. (*a*) The width of the end of a finger is about 1 cm, and so consider the fingertip to be a part of a sphere of diameter 1 cm. We assume that the electric field at the radius of the sphere is the minimum value that will produce breakdown in air. We use the same approach as in Examples 23-4 and 23-5.

$$V_{\text{surface}} = r_0 E_{\text{breakdown}} = (0.005\,\text{m})(3\times10^6\ \text{V/m}) = \boxed{15{,}000\,\text{V}}$$

Since this is just an estimate, we might expect anywhere from 10,000 V to 20,000 V.

(*b*) $$V_{\text{surface}} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r_0} = \frac{1}{4\pi\varepsilon_0}\frac{4\pi r_0^2\sigma}{r_0} \rightarrow$$

$$\sigma = V_{\text{surface}}\frac{\varepsilon_0}{r_0} = (15{,}000\,\text{V})\frac{(8.85\times10^{-12}\ \text{C}^2/\text{N}\bullet\text{m}^2)}{0.005\,\text{m}} = \boxed{2.7\times10^{-5}\ \text{C/m}^2}$$

Since this is an estimate, we might say the charge density is on the order of $30\,\mu\text{C/m}^2$.

75. In a **photocell**, ultraviolet (UV) light provides enough energy to some electrons in barium metal to eject them from the surface at high speed. See Fig. 23–36. To measure the maximum energy of the electrons, another plate above the barium surface is kept at a negative enough potential that the emitted electrons are slowed down and stopped, and return to the barium surface. If the plate voltage is −3.02 V (compared to the barium) when the fastest electrons are stopped, what was the speed of these electrons when they were emitted?

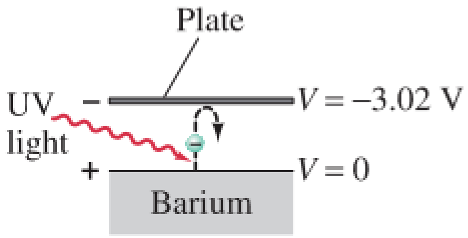

FIGURE 23–36 Problem 75.

75. The kinetic energy of the electrons (provided by the UV light) is converted completely to potential energy at the plate since they are stopped. Use energy conservation to find the emitted speed, taking the 0 of PE to be at the surface of the barium.

$$\text{KE}_{\text{initial}} = \text{PE}_{\text{final}} \rightarrow \tfrac{1}{2}mv^2 = qV \rightarrow$$

$$v = \sqrt{\frac{2qV}{m}} = \sqrt{\frac{2(-1.60\times10^{-19}\,\text{C})(-3.02\,\text{V})}{9.11\times10^{-31}\,\text{kg}}} = \boxed{1.03\times10^6\ \text{m/s}}$$

76. An electron is accelerated horizontally from rest in a television picture tube by a potential difference of 5500 V. It then passes between two horizontal plates 6.5 cm long and 1.3 cm apart that have a potential difference of 250 V (Fig. 23–37). At what angle θ will the electron be traveling after it passes between the plates?

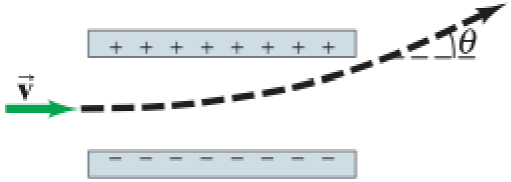

FIGURE 23–37
Problem 76.

76. To find the angle, the horizontal and vertical components of the velocity are needed. The horizontal component can be found using conservation of energy for the initial acceleration of the electron. That component is not changed as the electron passes through the plates. The vertical component can be found using the vertical acceleration due to the potential difference of the plates, and the time the electron spends between the plates.

Horizontal:

$$\mathrm{PE}_{\text{inital}} = \mathrm{KE}_{\text{final}} \rightarrow qV = \tfrac{1}{2}mv_x^2 \qquad t = \frac{\Delta x}{v_x}$$

Vertical:

$$F_{\mathrm{E}} = qE_y = ma = m\frac{(v_y - v_{y0})}{t} \rightarrow v_y = \frac{qE_y t}{m} = \frac{qE_y \Delta x}{mv_x}$$

Combined:

$$\tan\theta = \frac{v_y}{v_x} = \frac{\dfrac{qE_y\Delta x}{mv_x}}{v_x} = \frac{qE_y\Delta x}{mv_x^2} = \frac{qE_y\Delta x}{2qV} = \frac{E_y\Delta x}{2V} = \frac{\left(\dfrac{250\,\mathrm{V}}{0.013\,\mathrm{m}}\right)(0.065\,\mathrm{m})}{2(5500\,\mathrm{V})} = 0.1136$$

$$\theta = \tan^{-1} 0.1136 = \boxed{6.5^\circ}$$