2. The magnitude is $\Delta U = e\Delta V = 1.2 \times 10^9\,\mathrm{eV} = 1.2\,\mathrm{GeV}$.

5. The electric field produced by an infinite sheet of charge has magnitude $E = \sigma/2\varepsilon_0$, where σ is the surface charge density. The field is normal to the sheet and is uniform. Place the origin of a coordinate system at the sheet and take the x axis to be parallel to the field and positive in the direction of the field. Then the electric potential is

$$V = V_s - \int_0^x E\,dx = V_s - Ex\ ,$$

where V_s is the potential at the sheet. The equipotential surfaces are surfaces of constant x; that is, they are planes that are parallel to the plane of charge. If two surfaces are separated by Δx then their potentials differ in magnitude by $\Delta V = E\Delta x = (\sigma/2\varepsilon_0)\Delta x$. Thus,

$$\Delta x = \frac{2\varepsilon_0\,\Delta V}{\sigma} = \frac{2\left(8.85\times10^{-12}\,\mathrm{C^2/N\cdot m^2}\right)(50\,\mathrm{V})}{0.10\times10^{-6}\,\mathrm{C/m^2}} = 8.8\times10^{-3}\ \mathrm{m}\ .$$

21. A charge $-5q$ is a distance $2d$ from P, a charge $-5q$ is a distance d from P, and two charges $+5q$ are each a distance d from P, so the electric potential at P is

$$V = \frac{q}{4\pi\varepsilon_0}\left[-\frac{5}{2d} - \frac{5}{d} + \frac{5}{d} + \frac{5}{d}\right] = \frac{5q}{8\pi\varepsilon_0} .$$

The zero of the electric potential was taken to be at infinity.

31. We use Eq. 25-41:

$$\begin{aligned} E_x(x,y) &= -\frac{\partial V}{\partial x} = -\frac{\partial}{\partial x}\left((2.0\,\mathrm{V/m^2})x^2 - (3.0\,\mathrm{V/m^2})y^2\right) = -2(2.0\,\mathrm{V/m^2})x\ ; \\ E_y(x,y) &= -\frac{\partial V}{\partial y} = -\frac{\partial}{\partial y}\left((2.0\,\mathrm{V/m^2})x^2 - (3.0\,\mathrm{V/m^2})y^2\right) = 2(3.0\,\mathrm{V/m^2})y\ . \end{aligned}$$

We evaluate at $x = 3.0\,\mathrm{m}$ and $y = 2.0\,\mathrm{m}$ to obtain the magnitude of $\vec{E}$:

$$E = \sqrt{E_x^2 + E_y^2} = 17\ \mathrm{V/m}\ .$$

$\vec{E}$ makes an angle θ with the positive x axis, where

$$\theta = \tan^{-1}\left(\frac{E_y}{E_x}\right) = 135^\circ\ .$$

39. (a) Let $\ell = 0.15\,\mathrm{m}$ be the length of the rectangle and $w = 0.050\,\mathrm{m}$ be its width. Charge q_1 is a distance ℓ from point A and charge q_2 is a distance w, so the electric potential at A is

$$\begin{aligned} V_A &= \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{\ell} + \frac{q_2}{w}\right] \\ &= \left(8.99 \times 10^9\,\mathrm{N\cdot m^2/C^2}\right)\left[\frac{-5.0 \times 10^{-6}\,\mathrm{C}}{0.15\,\mathrm{m}} + \frac{2.0 \times 10^{-6}\,\mathrm{C}}{0.050\,\mathrm{m}}\right] \\ &= 6.0 \times 10^4 \ \mathrm{V}\ . \end{aligned}$$

(b) Charge q_1 is a distance w from point b and charge q_2 is a distance ℓ, so the electric potential at B is

$$\begin{aligned} V_B &= \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{w} + \frac{q_2}{\ell}\right] \\ &= \left(8.99 \times 10^9\,\mathrm{N\cdot m^2/C^2}\right)\left[\frac{-5.0 \times 10^{-6}\,\mathrm{C}}{0.050\,\mathrm{m}} + \frac{2.0 \times 10^{-6}\,\mathrm{C}}{0.15\,\mathrm{m}}\right] \\ &= -7.8 \times 10^5 \ \mathrm{V}\ . \end{aligned}$$

(c) Since the kinetic energy is zero at the beginning and end of the trip, the work done by an external agent equals the change in the potential energy of the system. The potential energy is the product of the charge q_3 and the electric potential. If U_A is the potential energy when q_3 is at A and U_B is the potential energy when q_3 is at B, then the work done in moving the charge from B to A is $W = U_A - U_B = q_3(V_A - V_B) = (3.0 \times 10^{-6}\,\mathrm{C})(6.0 \times 10^4\,\mathrm{V} + 7.8 \times 10^5\,\mathrm{V}) = 2.5\,\mathrm{J}$.

(d) The work done by the external agent is positive, so the energy of the three-charge system increases.

(e) and (f) The electrostatic force is conservative, so the work is the same no matter which path is used.

51. If the electric potential is zero at infinity, then the potential at the surface of the sphere is given by $V = q/4\pi\varepsilon_0 r$, where q is the charge on the sphere and r is its radius. Thus

$$q = 4\pi\varepsilon_0 rV = \frac{(0.15\,\mathrm{m})(1500\,\mathrm{V})}{8.99 \times 10^9\,\mathrm{N{\cdot}m^2/C^2}} = 2.5 \times 10^{-8}\ \mathrm{C}\ .$$