9. (a) All the charge is the same distance R from C, so the electric potential at C is

$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q_1}{R} - \frac{6Q_1}{R}\right) = -\frac{5Q_1}{4\pi\varepsilon_0 R} = -\frac{5(8.99\times10^9\ \mathrm{N\cdot m^2/C^2})(7.07\times10^{-12}\,\mathrm{C})}{8.20\times10^{-2}\ \mathrm{m}} = -3.88\ \mathrm{V},$$

where the zero was taken to be at infinity.

(b) All the charge is the same distance from P. That distance is $\sqrt{R^2+D^2}$, so the electric potential at P is

$$\begin{aligned} V &= \frac{1}{4\pi\varepsilon_0}\left[\frac{Q_1}{\sqrt{R^2+D^2}} - \frac{6Q_1}{\sqrt{R^2+D^2}}\right] = -\frac{5Q_1}{4\pi\varepsilon_0\sqrt{R^2+D^2}} \\ &= -\frac{5(8.99\times10^9\ \mathrm{N\cdot m^2/C^2})(7.07\times10^{-12}\,\mathrm{C})}{\sqrt{(8.20\times10^{-2}\ \mathrm{m})^2 + (2.05\times10^{-2}\ \mathrm{m})^2}} \\ &= -3.76\ \mathrm{V}. \end{aligned}$$

13. We use the conservation of energy principle. The initial potential energy is $U_i = q^2/4\pi\varepsilon_0 r_1$, the initial kinetic energy is $K_i = 0$, the final potential energy is $U_f = q^2/4\pi\varepsilon_0 r_2$, and the final kinetic energy is $K_f = \frac{1}{2}mv^2$, where v is the final speed of the particle. Conservation of energy yields

$$\frac{q^2}{4\pi\varepsilon_0 r_1} = \frac{q^2}{4\pi\varepsilon_0 r_2} + \frac{1}{2}mv^2 .$$

The solution for v is

$$v = \sqrt{\frac{2q^2}{4\pi\varepsilon_0 m}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)} = \sqrt{\frac{(8.99\times10^9\ \mathrm{N\cdot m^2/C^2})(2)(3.1\times10^{-6}\,\mathrm{C})^2}{20\times10^{-6}\mathrm{kg}}\left(\frac{1}{0.90\times10^{-3}\,\mathrm{m}} - \frac{1}{1.5\times10^{-3}\,\mathrm{m}}\right)}$$
$$= 1960\,\mathrm{m/s}$$

and the corresponding momentum is

$$p = mv = (20\times10^{-6}\mathrm{kg})(1960\ \mathrm{m/s}) = 3.9\times10^{-2}\mathrm{kg\cdot m/s}$$

17. **THINK** The component of the electric field $\vec{E}$ in a given direction is the negative of the rate at which potential changes with distance in that direction.

EXPRESS With $V = 2.00xyz^2$, we apply Eq. 24–41 to calculate the x, y, and z components of the electric field:

$$E_x = -\frac{\partial V}{\partial x} = -2.00yz^2$$
$$E_y = -\frac{\partial V}{\partial y} = -2.00xz^2$$
$$E_z = -\frac{\partial V}{\partial z} = -4.00xyz$$

which, at (x, y, z) = (–1.00 m, –2.00 m, 4.00 m), gives

$$(E_x, E_y, E_z) = (+64.0 \text{ V/m}, +32.0 \text{ V/m}, -32.0 \text{ V/m}).$$

ANALYZE The magnitude of the field is therefore

$$\begin{aligned}|\vec{E}| &= \sqrt{E_x^2 + E_y^2 + E_z^2} = \sqrt{(64.0 \text{ V/m})^2 + (+32.0 \text{ V/m})^2 + (-32.0 \text{ V/m})^2} \\ &= 78.4 \text{ V/m} = 78.4 \text{ N/C}.\end{aligned}$$

LEARN If the electric potential increases along some direction, say x, with $\partial V / \partial x > 0$, then there is a corresponding non-vanishing component of $\vec{E}$ in the opposite direction $(-E_x \neq 0)$.

41. **THINK** Ampere is the SI unit for current. An ampere is one coulomb per second.

EXPRESS To calculate the total charge through the circuit, we note that $1\text{ A} = 1\text{ C/s}$ and $1\text{ h} = 3600\text{ s}$.

ANALYZE (a) Thus,

$$q = 70\text{A}\cdot\text{h} = \left(70\frac{\text{C}\cdot\text{h}}{\text{s}}\right)\left(3600\frac{\text{s}}{\text{h}}\right) = 2.52\times10^{5}\text{ C} \approx 2.5\times10^{5}\text{ C}.$$

(b) The change in potential energy is $\Delta U = q\,\Delta V = (2.52\times10^{5}\text{ C})(25\text{ V}) = 6.3\times10^{6}\text{ J}$.

LEARN Potential difference is the change of potential energy per unit charge. Unlike electric field, potential difference is a scalar quantity.

47. Let the distance in question be r. The initial kinetic energy of the electron is $K_i = \frac{1}{2} m_e v_i^2$, where $v_i = 3.2 \times 10^5$ m/s. As the speed doubles, K becomes $4K_i$. Thus

$$\Delta U = \frac{-e^2}{4\pi\varepsilon_0 r} = -\Delta K = -(4K_i - K_i) = -3K_i = -\frac{3}{2} m_e v_i^2 ,$$

or

$$r = \frac{2e^2}{3(4\pi\varepsilon_0) m_e v_i^2} = \frac{2\left(1.6\times10^{-19}\,\mathrm{C}\right)^2\left(8.99\times10^9\,\mathrm{N\cdot m^2/C^2}\right)}{3\left(9.11\times10^{-31}\,\mathrm{kg}\right)\left(1.6\times10^5\,\mathrm{m/s}\right)^2} = 6.6\times10^{-9}\,\mathrm{m}.$$