EXAMPLE 17–4 Potential due to a positive or a negative charge. Determine the potential at a point 0.50 m (*a*) from a $+20\,\mu C$ point charge, (*b*) from a $-20\,\mu C$ point charge.

APPROACH The potential due to a point charge is given by Eq. 17–5, $V = kQ/r$.

SOLUTION (*a*) At a distance of 0.50 m from a positive $20\,\mu C$ charge, the potential is

$$V = k\frac{Q}{r}$$

$$= \left(9.0 \times 10^9\,\mathrm{N \cdot m^2/C^2}\right)\left(\frac{20 \times 10^{-6}\,\mathrm{C}}{0.50\,\mathrm{m}}\right) = 3.6 \times 10^5\,\mathrm{V}.$$

(*b*) For the negative charge,

$$V = \left(9.0 \times 10^9\,\mathrm{N \cdot m^2/C^2}\right)\left(\frac{-20 \times 10^{-6}\,\mathrm{C}}{0.50\,\mathrm{m}}\right) = -3.6 \times 10^5\,\mathrm{V}.$$

NOTE Potential can be positive or negative. In contrast to calculations of electric field magnitudes, for which we usually ignore the sign of the charges, it is important to include a charge's sign when we find electric potential.

PROBLEM SOLVING
Keep track of charge signs for electric potential

EXAMPLE 17–5 Work done to bring two positive charges close together. What minimum work must be done by an external force to bring a charge $q = 3.00\,\mu C$ from a great distance away (take $r = \infty$) to a point 0.500 m from a charge $Q = 20.0\,\mu C$?

APPROACH To find the work we cannot simply multiply the force times distance because the force is not constant. Instead we can set the change in potential energy equal to the (positive of the) work required of an *external* force (Chapter 6), and Eq. 17–3: $W = \Delta \mathrm{PE} = q(V_b - V_a)$. We get the potentials V_b and V_a using Eq. 17–5.

CAUTION
We cannot use $W = Fd$ if F is not constant

SOLUTION The work required is equal to the change in potential energy:

$$W = q(V_b - V_a) = q\left(\frac{kQ}{r_b} - \frac{kQ}{r_a}\right),$$

where $r_b = 0.500\,\mathrm{m}$ and $r_a = \infty$. The right-hand term within the parentheses is zero $(1/\infty = 0)$ so

$$W = \left(3.00 \times 10^{-6}\,\mathrm{C}\right)\frac{\left(8.99 \times 10^9\,\mathrm{N \cdot m^2/C^2}\right)\left(2.00 \times 10^{-5}\,\mathrm{C}\right)}{(0.500\,\mathrm{m})} = 1.08\,\mathrm{J}.$$

NOTE We could not use Eqs. 17–4 here because they apply *only* to uniform fields. But we did use Eq. 17–3 because it is always valid.

EXERCISE B What work is required to bring a charge $q = 3.00\,\mu C$ originally a distance of 1.50 m from a charge $Q = 20.0\,\mu C$ until it is 0.50 m away?

To determine the electric field at points near a collection of two or more point charges requires adding up the electric fields due to each charge. Since the electric field is a vector, this can be time consuming or complicated. To find the electric potential at a point due to a collection of point charges is far easier, since the electric potential is a scalar, and hence you only need to add numbers together without concern for direction. This is a major advantage in using electric potential for solving Problems. We do have to include the signs of charges, however.

Potentials add as scalars (fields add as vectors)