4. An ion accelerated through a potential difference of 60.0 V has its potential energy decreased by $1.92 \times 10^{-17}$ J. Calculate the charge on the ion.

$$\Delta PE_e = q(\Delta V) = q(V_f - V_i)$$

so

$$q = \frac{\Delta PE_e}{V_f - V_i} = \frac{-1.92 \times 10^{-17}}{60.0 \text{ J/C}} = -3.20 \times 10^{-19} \text{ C}$$

6. To recharge a 12-V battery, a battery charger must move $3.6 \times 10^5 \text{ C}$ of charge from the negative terminal to the positive terminal. How much work is done by the charger? Express your answer in Joules.

Since potential difference is work per unit charge $\Delta V = \frac{W}{q}$, the work done is

$$W = q(\Delta V) = (3.6 \times 10^5 \text{ C})(+12 \text{ J/C}) = 4.3 \times 10^6 \text{ J}$$

13. (a) Find the electric potential, taking zero at infinity, at the upper right corner (the corner without a charge) of the rectangle in the figure below.

(b) Repeat if the $2.00 \mu\text{C}$ charge is replaced with a $-2.00 \mu\text{C}$ charge.

(a) Calling the $2.00 \mu\text{C}$ charge $q_3$,

$$V = \sum \frac{kq_1q_2}{r_1} = k \left( \frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{\sqrt{r_1^2 + r_2^2}} \right)$$

$$= \left( 8.99 \times 10^9 \frac{\text{N} \cdot \text{m}^2}{\text{C}^2} \right) \left[ \frac{8.00 \times 10^{-6} \text{ C}}{0.060 \text{ m}} + \frac{4.00 \times 10^{-6} \text{ C}}{0.030 \text{ m}} + \frac{2.00 \times 10^{-6} \text{ C}}{\sqrt{(0.060 \text{ m})^2 + (0.030 \text{ m})^2}} \right]$$

$$V = 2.67 \times 10^6 \text{ V}$$

(b) Replacing $2.00 \times 10^{-6} \text{ C}$ by $-2.00 \times 10^{-6} \text{ C}$ in part (a) yields

$$V = 2.13 \times 10^6 \text{ V}$$
21. A small spherical object carries a charge of 8.00 nC. At what distance from the center of the object is the potential equal to 100 V? 50.0 V? 25.0 V? Is The spacing of the equipotentials proportional to the change in voltage?

\[ V = \frac{kQ}{r} \]

so

\[ r = \frac{kQ}{V} = \left( \frac{8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2}{V} \right) \left( 8.00 \times 10^{-9} \text{ C} \right) = \frac{71.9 \text{ V} \cdot \text{m}}{V} \]

For \( V = 100 \text{ V}, 50.0 \text{ V}, \text{ and } 25.0 \text{ V}, \ r = 0.719 \text{ m}, 1.44 \text{ m}, \text{ and } 2.88 \text{ m} \)

The radii are inversely proportional to the potential.

24. Four point charges each having a charge of \( Q \) are located at the corners of a square having sides of length \( a \). Find the symbolic expressions for
(a) the electric potential at the center of the square due to the four charges,
(b) the work required to bring a fifth charge \( q \) from infinity to the center of the square.

(a) The distance from any one of the corners of the square to the point at the center is one half the length of the diagonal of the square, or

\[ r = \frac{\text{diagonal}}{2} = \frac{\sqrt{a^2 + a^2}}{2} = \frac{a\sqrt{2}}{2} = a \]

Since the charges have equal magnitudes and are all the same distance from the center of the square, they make equal contributions to the total potential. Thus,

\[ V_{\text{total}} = 4V_{\text{single charge}} = 4 \frac{kQ}{r} = 4 \frac{kQ}{a/\sqrt{2}} = 4\sqrt{2}k_e \frac{Q}{a} \]

(b) The work required to carry charge \( q \) from infinity to the point at the center of the square is equal to the increase in the electric potential energy of the charge, or

\[ W = PE_{\text{center}} - PE_{\infty} = qV_{\text{total}} - 0 = q \left( 4\sqrt{2}k_e \frac{Q}{a} \right) = 4\sqrt{2}k_e \frac{qQ}{a} \]
26. (a) When a 9.00 V battery is connected to the plates of a capacitor, it stores a charge of 27.0 µC. What is the value of the capacitance?
(b) If the same capacitor is connected to a 12.0 V battery, what charge is stored?

\[
(a) \quad C = \frac{Q}{\Delta V} = \frac{27.0 \, \mu C}{9.00 \, V} = 3.00 \, \mu F
\]

\[
(b) \quad Q = C(\Delta V) = (3.00 \, \mu F)(12.0 \, V) = 36.0 \, \mu C
\]

28. (a) How much charge is on each plate of a 4.00 µF capacitor when it is connected to a 12.0 V battery?
(b) If this same capacitor is connected to a 1.50 V battery, what charge is stored?

\[
(a) \quad Q = C(\Delta V) = (4.00 \times 10^{-6} \, \text{F})(12.0 \, \text{V}) = 48.0 \times 10^{-6} \, \text{C} = 48.0 \, \mu C
\]

\[
(b) \quad Q = C(\Delta V) = (4.00 \times 10^{-6} \, \text{F})(1.50 \, \text{V}) = 6.00 \times 10^{-6} \, \text{C} = 6.00 \, \mu C
\]