

53. (a) The electric potential is the sum of the contributions of the individual spheres. Let  $q_1$  be the charge on one,  $q_2$  be the charge on the other, and  $d$  be their separation. The point halfway between them is the same distance  $d/2$  ( $= 1.0\text{ m}$ ) from the center of each sphere, so the potential at the halfway point is

$$V = \frac{q_1 + q_2}{4\pi\epsilon_0 d/2} = \frac{(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2)(1.0 \times 10^{-8} \text{ C} - 3.0 \times 10^{-8} \text{ C})}{1.0 \text{ m}} = -1.80 \times 10^2 \text{ V} .$$

- (b) The distance from the center of one sphere to the surface of the other is  $d - R$ , where  $R$  is the radius of either sphere. The potential of either one of the spheres is due to the charge on that sphere and the charge on the other sphere. The potential at the surface of sphere 1 is

$$\begin{aligned} V_1 &= \frac{1}{4\pi\epsilon_0} \left[ \frac{q_1}{R} + \frac{q_2}{d - R} \right] \\ &= (8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2) \left[ \frac{1.0 \times 10^{-8} \text{ C}}{0.030 \text{ m}} - \frac{3.0 \times 10^{-8} \text{ C}}{2.0 \text{ m} - 0.030 \text{ m}} \right] \\ &= 2.9 \times 10^3 \text{ V} . \end{aligned}$$

The potential at the surface of sphere 2 is

$$\begin{aligned} V_2 &= \frac{1}{4\pi\epsilon_0} \left[ \frac{q_1}{d - R} + \frac{q_2}{R} \right] \\ &= (8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2) \left[ \frac{1.0 \times 10^{-8} \text{ C}}{2.0 \text{ m} - 0.030 \text{ m}} - \frac{3.0 \times 10^{-8} \text{ C}}{0.030 \text{ m}} \right] \\ &= -8.9 \times 10^3 \text{ V} . \end{aligned}$$