

Answer to Essential Question 17.3: No. If we re-do the calculation $\Delta U = q\Delta V$ we find that the change in potential energy is -40 mJ. Because potential energy is a scalar, -40 mJ is quite different from $+40$ mJ. We have to force a positively charged object to move to a region of higher potential (and higher potential energy). A negatively charged object already feels a force toward higher potential, and moving in that direction lowers the potential energy, so we have to pull back on it to cause it to stop at the point of higher potential.

17-4 Electric Potential for a Point Charge

A point charge is generally an object like a small charged ball. Such objects contribute to both the electric field and the electric potential in the space around them. The contribution of an object of charge Q to the electric potential at a point a distance r away is given by:

$$V = \frac{kQ}{r}. \quad (\text{Equation 17.4: Electric potential from a point charge})$$

Interestingly, the potential outside a charged sphere that has a spherically symmetric charge distribution is also given by Equation 17.6, where Q is the total charge on the sphere and r is the distance from the center of the sphere to a point outside the sphere. In a two-dimensional diagram of this situation, such as that in Figure 17.7, the equipotential lines are circles centered on the object. Note that the potential difference (which is more important than the value of the potential at a point) between one equipotential line and the next is a constant value, but the lines get further apart as you move away from the object because the field decreases - the farther you are from the object, the smaller its influence.

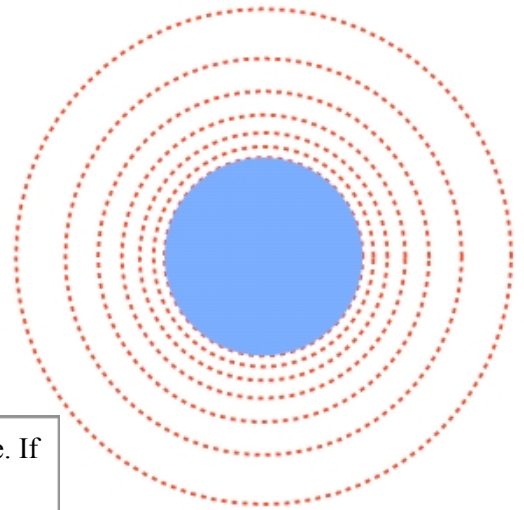


Figure 17.7: Equipotentials near a charged conducting sphere. If the equipotential at the surface of the sphere connects all the points where the potential is -10 J/C, the equipotentials at gradually increasing distances from the sphere connect all points of potential -9 J/C, -8 J/C, -7 J/C, -6 J/C, -5 J/C, and -4 J/C, respectively. The field points in the direction of decreasing potential, toward the center of the sphere.

EXAMPLE 17.4 – Calculating the electric potential

Two balls are on the x -axis, a ball of charge $+q$ at $x = 0$ and a ball of charge $+9q$ at $x = +4a$.

- (a) Find the electric potential at: (i) the point halfway between them, and (ii) $x = +a$, where the net electric field is zero.
 (b) Graph the electric potential at points along the axis between $x = -4a$ and $x = +8a$.

SOLUTION

As usual, let's begin with a diagram of the situation. This is shown in Figure 17.8.

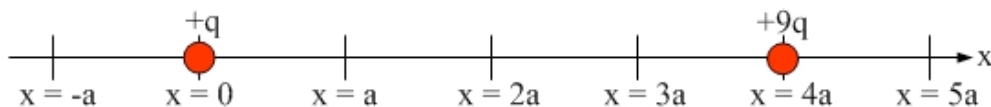


Figure 17.8: The position of the two charged balls on the x -axis.

To solve part (a) we use superposition, the idea that the potential at any point is simply the sum of the potential at that point from each of the objects.

(a)(i) The point halfway between the objects is $x = +2a$. Remembering that the r in the equation represents the distance from an object with mass to the point we're considering, which also happens to be $2a$ for both objects in this case, we get:

$$V_{net} = V_{+q} + V_{+9q} = +\frac{kq}{2a} + \frac{k(9q)}{2a} = +\frac{10kq}{2a} = +\frac{5kq}{a}.$$

(a)(ii) The point $x = +a$ is a distance a from the object of charge $+q$ and $3a$ from the object of charge $+9q$. The net potential is again the sum of the two individual contributions:

$$V_{net} = V_{+q} + V_{+9q} = +\frac{kq}{a} + \frac{k(9q)}{3a} = +\frac{4kq}{a}.$$

(b) To plot a graph of the potential as a function of position, we should have a general expression for the net potential. This is:

$$V_{net} = V_{+q} + V_{+9q} = +\frac{kq}{|x|} + \frac{k(9q)}{|4a - x|}.$$

The graph of this function between $x = -4a$ and $x = +8a$ is shown in Figure 17.9.

Related End-of-Chapter Exercises: 10-12, 56, 57.

There is a connection between the electric potential and the electric field that the graph in Figure 17.9 can help us to understand. The electric field is zero at $x = +a$. Does anything special happen at $x = +a$ on the potential graph? It turns out that, at $x = +a$, the graph reaches a local minimum, so the slope of the potential-vs.-position graph is zero at that point.

For $0 < x < +a$, the electric field along the axis points in the positive x direction while the slope of the potential is a negative value. Just the opposite happens in the range $+a < x < +4a$. The electric field is actually the negative of the slope of the potential-vs.-position graph. So, the potential graph is rather powerful, telling us at a glance something about where the electric field is strongest and in what direction it is, while at the same time giving us information about how potential energy would change if we placed another object with charge at a particular location.

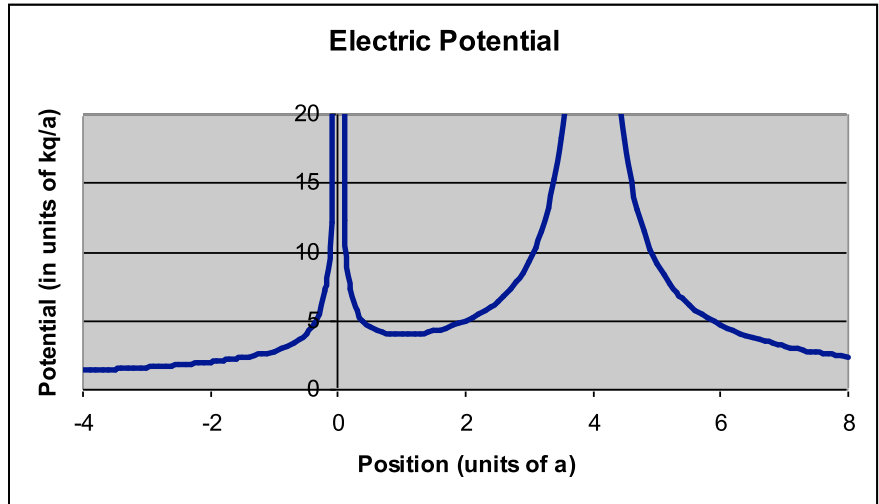


Figure 17.9: Graph of the electric potential along the axis near the balls. Note how the potential approaches positive infinity as you approach either of the balls.

Essential Question 17.4: What do we have to account for in determining net electric field that we do not have to account for in determining the net electric potential?