Physics for Scientists & Engineers 2

Spring Semester 2005

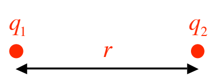
Lecture 10

Electric Potential Energy for a System of Particles

- Yesterday we discussed the electric potential energy of a point charge in a fixed electric field.
- Now we introduce the concept of the electric potential energy of a system of point charges.
- In the case of a fixed electric field, the point charge did not affect the electric field that did work on the charge
- Now we consider a system of point charges that produce the electric potential themselves
- To study this situation, we begin with a system of charges that are infinitely far apart.
- To bring these charges into proximity with each other, we must do work on the charges, which changes the electric potential energy of that system.

Electric Potential Energy for a System of Particles (2)

- To illustrate the concept of the electric potential energy of a system of particles we calculate the electric potential energy of a system of two point charges, q_1 and q_2
- We start our calculation with the two charges at infinity
- We then bring in point charge q_1



- Because there is no electric field and no corresponding electric force, this action requires no work to be done on the charge
- Keeping this charge stationary, we bring the second point charge q_2 in from infinity to a distance r from q_1

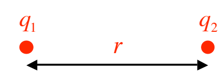
Electric Potential Energy for a System of Particles (3)

- We can write the electric potential of this two charge system as

$$U = q_2 V$$

where

$$V = \frac{kq_1}{r}$$



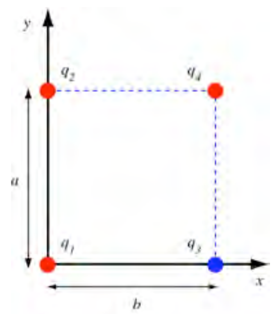
- Which means that the electric potential of the two charge system is

$$U = \frac{kq_1 q_2}{r}$$

- If the two point charges have the same sign, then we must do work on the particles to bring them together and keep them stationary
- If the two charges have opposite signs, we must do negative work on the system to bring them together from infinity and hold them motionless.

Example - Four Charges

- Consider a system of four point charges as shown. The four point charges have the values q_1 =+1.0 μC, q_2 = +2.0 μC, q_3 = -3.0 μC, and q_4 = +4.0 μC. The charges are placed such that a = 6.0 m and b = 4.0 m.
- What is the electric potential energy of this system of four point charges?



Example - Four Charges (2)

We start with q_1

We bring in q_1 from infinity and place it at $(0,0)$

This action does not change the electric potential energy of the system

Now we bring in q_2 from infinity and place it at $(0,a)$

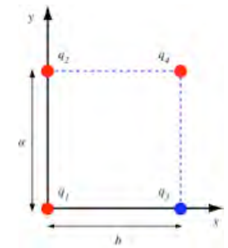
the electric potential energy of the system is now

$$U = k\frac{q_1 q_2}{a}$$

Now we bring in q_3 from infinity and place it at $(b,0)$

the electric potential energy of the system is now

$$U = \underbrace{\frac{kq_1q_2}{a}}_{q_1 \text{ with } q_2} + \underbrace{\frac{kq_1q_3}{b}}_{q_1 \text{ with } q_3} + \underbrace{\frac{kq_2q_3}{\sqrt{a^2+b^2}}}_{q_2 \text{ with } q_3}$$



Example - Four Charges (3)

Now we bring in q_4 from infinity and place it at (b,a)

the electric potential energy of the system is now

$$U = \underbrace{\frac{kq_1q_2}{a}}_{q_1 \text{ with } q_2} + \underbrace{\frac{kq_1q_3}{b}}_{q_1 \text{ with } q_3} + \underbrace{\frac{kq_2q_3}{\sqrt{a^2+b^2}}}_{q_2 \text{ with } q_3} + \underbrace{\frac{kq_1q_4}{\sqrt{a^2+b^2}}}_{q_1 \text{ with } q_4} + \underbrace{\frac{kq_2q_4}{b}}_{q_2 \text{ with } q_4} + \underbrace{\frac{kq_3q_4}{a}}_{q_3 \text{ with } q_4}$$

$$U = \left(3.0\cdot 10^{-3}\text{ J}\right) + \left(-6.7\cdot 10^{-3}\text{ J}\right) + \left(-4.2\cdot 10^{-5}\text{ J}\right) + \left(5.0\cdot 10^{-3}\text{ J}\right) + \left(1.8\cdot 10^{-2}\text{ J}\right) + \left(-1.8\cdot 10^{-2}\text{ J}\right) = 1.2\cdot 10^{-3}\text{ J}$$