Physics for Scientists & Engineers 2
Spring Semester 2005
Lecture 10

January 25, 2005
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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 \( U = q_1 V \) 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.
• Consider a system of four point charges as shown. The four point charges have the values \( q_1 = +1.0 \text{ } \mu \text{C}, q_2 = +2.0 \text{ } \mu \text{C}, q_3 = -3.0 \text{ } \mu \text{C}, \) and \( q_4 = +4.0 \text{ } \mu \text{C}. \) The charges are placed such that \( a = 6.0 \text{ m} \) and \( b = 4.0 \text{ m}. \n\)
• What is the electric potential energy of this system of four point charges?

\[
U = k \left( \frac{q_1 q_2}{a} + \frac{kq_1 q_3}{b \sqrt{a^2 + b^2}} + \frac{kq_2 q_3}{a \sqrt{a^2 + b^2}} + \frac{kq_2 q_4}{b} + \frac{kq_3 q_4}{a} \right)
\]

\[
U = \left( \frac{3.0 \cdot 10^{-3}}{1} \right) + \left( -6.7 \cdot 10^{-3} \right) + \left( -4.2 \cdot 10^{-3} \right) + \left( -4.1 \cdot 10^{-3} \right) + \left( 5.0 \cdot 10^{-3} \right) + \left( 1.8 \cdot 10^{-3} \right) + \left( -1.8 \cdot 10^{-3} \right) = 1.2 \cdot 10^{-3} \text{ J}
\]