Chapter 16: Electric Potential and Electric Potential Energy

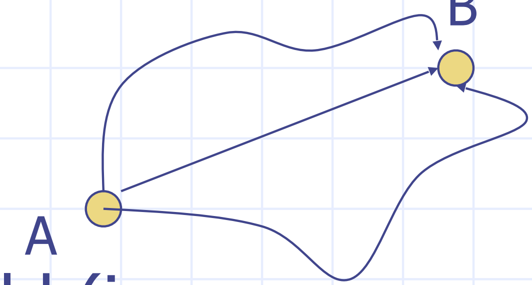
- From our studies of work and energy (Chaps. 6 and 7), we know that when a force acts on an object and displaces it, work is done on the object

$$W_{\text{int}} = \int \vec{F} \cdot d\vec{s} = -\Delta U$$

- This also results in a change in potential energy, if the force is a conservative force (i.e, internal). Since, the electric force is conservative, we can write the change in potential energy for a test charge in an electric field as

$$\Delta U = -q_0 \int \vec{E} \cdot d\vec{s}$$

- Since, the force is conservative, displacement of the test charge from point A to point B is independent of the path



$$\Delta U = U_B - U_A = -q_0 \int_A^B \vec{E} \cdot d\vec{s}$$

- Similar to our definition of the electric field (i.e. independent of the test charge), it is useful to remove q_0 from the definition of electric potential energy to give

$$\boxed{\frac{U}{q_0} = V}$$

- Where V is the electric potential with units of
  1 J/ 1 C = 1 volt or 1 V
- Similar to U, the electric potential energy, V is a scalar

- Then the potential difference is given by

$$\Delta V = \frac{\Delta U}{q_0} = -\int_A^B \vec{E} \cdot d\vec{s} = V_B - V_A$$

- Usually, it is convenient to take V_A=0 (or U_A=0)
- If an external force acts on the "test-charge-electric-field" system, work (from surroundings) is done on the system

$$W_{\text{surr}} = \Delta U = q_0 \Delta V$$

- Or, it takes 1 J of work to move a 1 C charge through a potential difference of 1 V
- Also, we see from the work integral form of V, that [V]=[N/C][m] or [N/C]=[V/m]
- So, electric field is the "rate" of change of the electric potential with position

Uniform Electric Field

- If the electric field is uniform and we displace the test charge at some angle with respect to the direction of W, the line integral simplifies

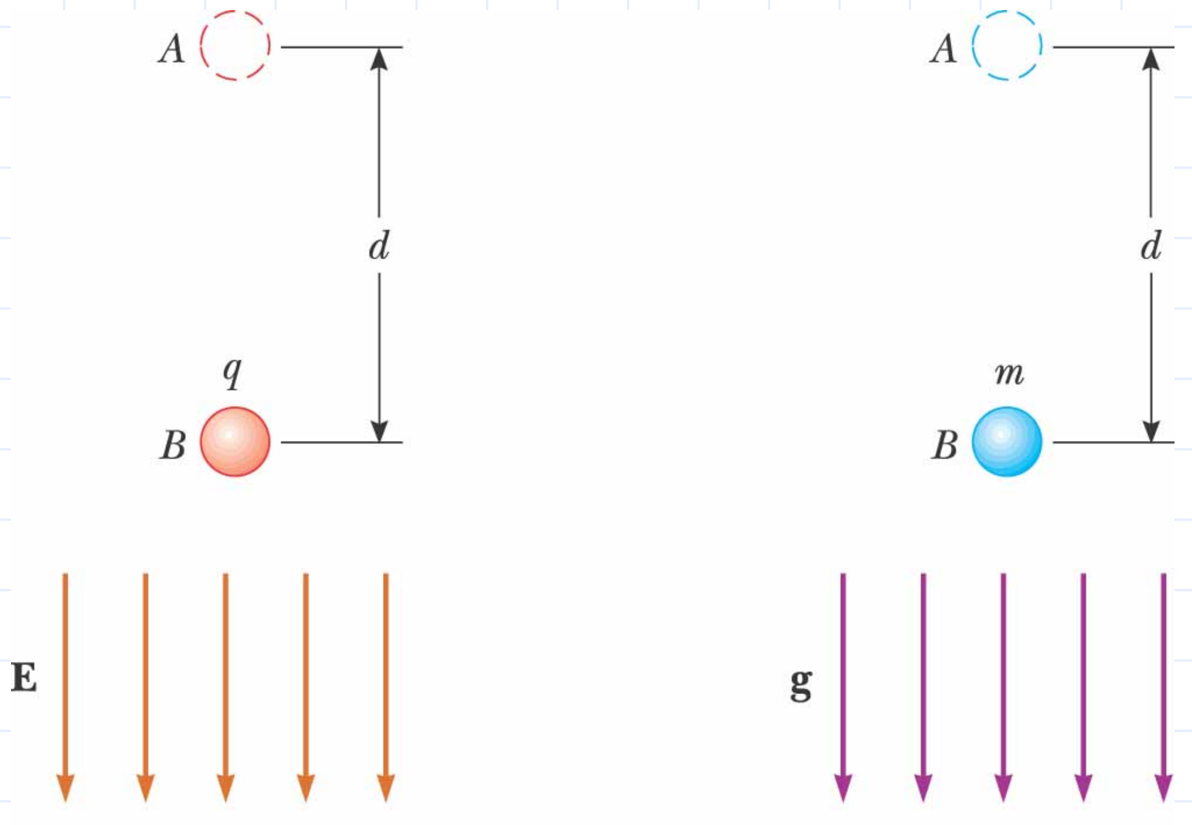
$$\int \vec{E}\cdot d\vec{s} = E\cos\theta \int ds$$

$$E\cos\theta \int_A^B ds = Ed\cos\theta$$

For $\theta=0$

$$\int \vec{E}\cdot d\vec{s} = Ed$$

$$\Delta V = -Ed$$

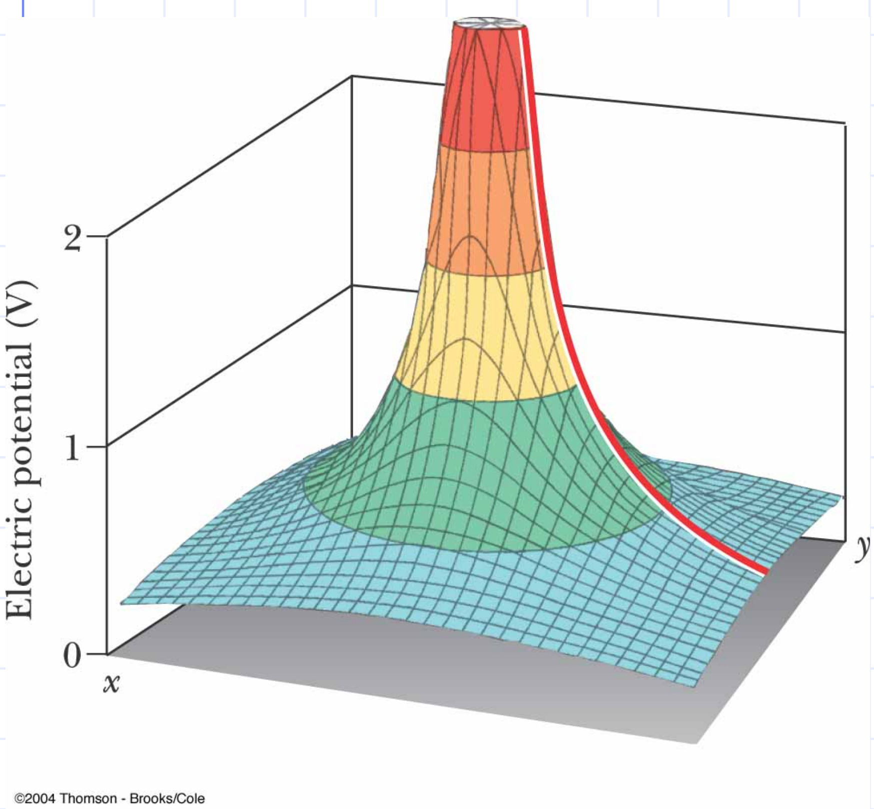


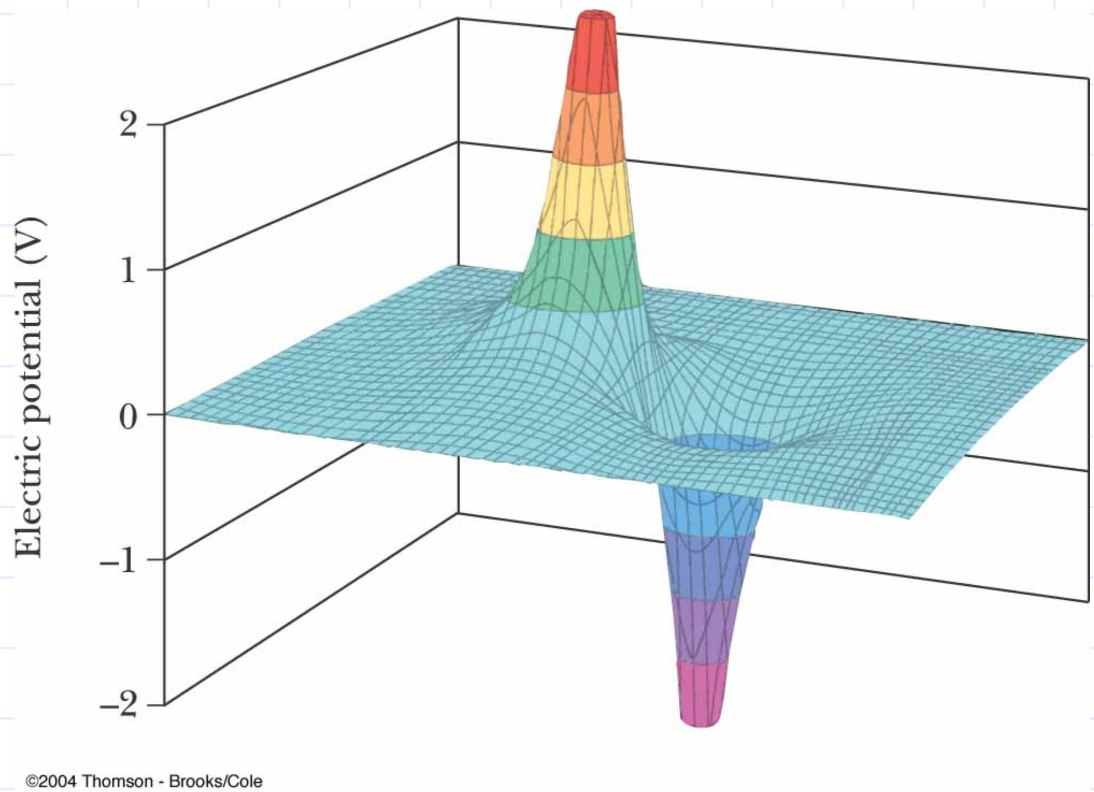
Example Problem

- Suppose an electron is released from rest in a uniform electric field whose magnitude is 5.90×10^3 V/m. (a) Through what potential difference will it have passed after moving 1.00 cm? (b) How fast will the electron be moving after it has traveled 1.00 cm?

Electric Potential and Electric Potential Energy due to Point Charges

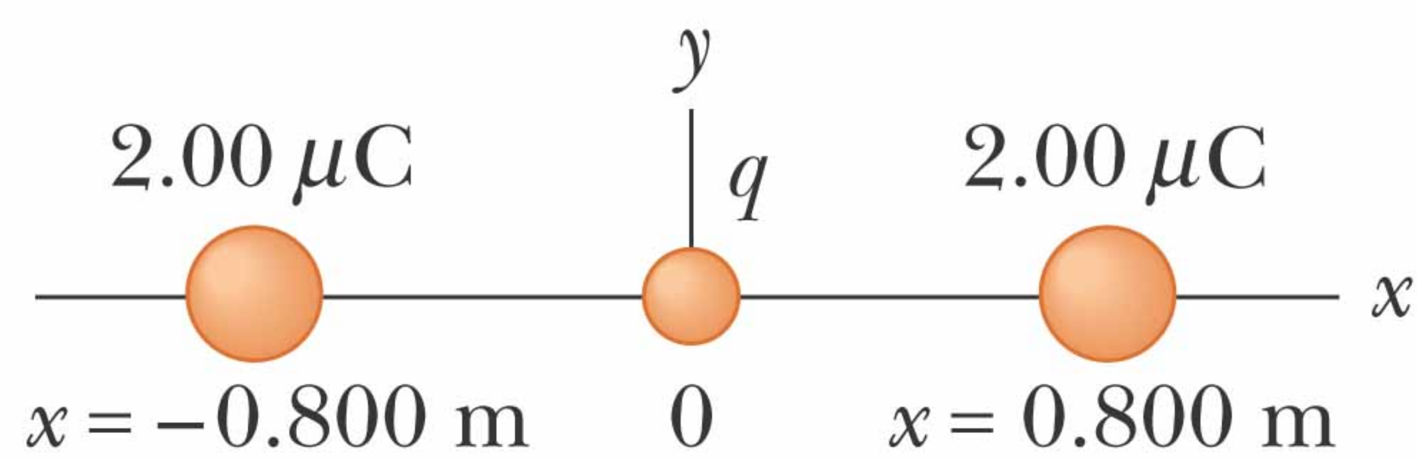
- Proton
- Dipole





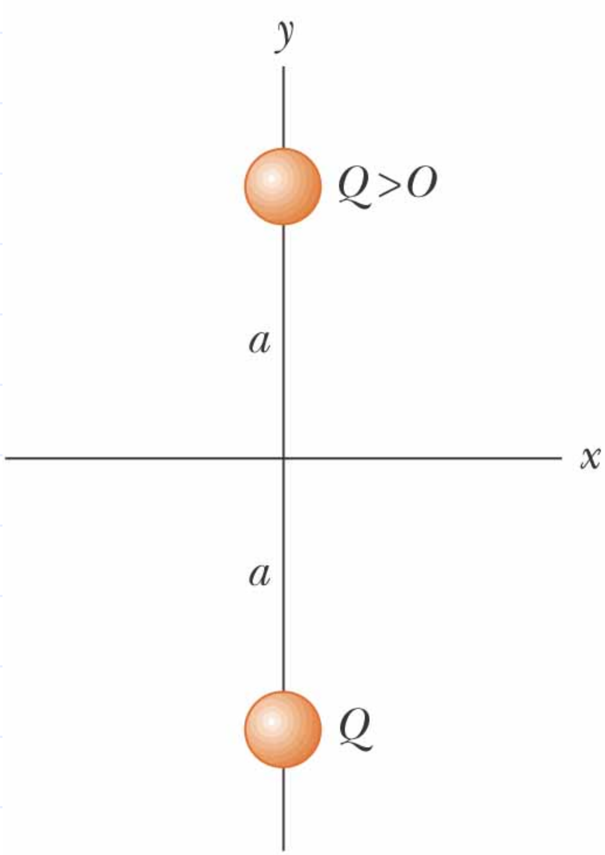
Example Problem

- Given two 2.00-μC charges, as shown in the figure, and a positive test charge $q=1.28\times10^{-18}$ C at the origin. (a) What is the net force exerted by the two 2.00-μC charges on the test charge q? (b) What is the electric field at the origin due to the two 2.00-μC charges? (c) What is the electric potential at the origin due to the two 2.00-μC?



Example Problem

- Two point charges of equal magnitude are located along the y axis equal distances above and below the origin as shown. (a) Plot a graph of the potential at points along the x axis over the interval $-3a<x<3a$ in units of k_eQ/a. (b) Let the charge located at –a be negative and plot the potential along the y axis over the interval $-4a < y < 4a$.



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Two positive charges (x=0)