Chapter 25

Electric Potential

Electrical Potential Energy

- When a test charge is placed in an electric field, it experiences a force
  - $\mathbf{F} = q_o\mathbf{E}$
- The force is conservative and the work by the electric field is $\mathbf{F}\cdot d\mathbf{s} = q_o\mathbf{E}\cdot d\mathbf{s}$
- The potential energy of the charge-field system is changed by

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

Electric Potential Energy, final

- Because $q_o\mathbf{E}$ is conservative, the line integral does not depend on the path taken by the charge

Electric Potential

- The potential energy per unit charge, U/q_o, is the **electric potential**
  - The potential is independent of the value of q_o
  - The potential has a value at every point in an electric field
- The electric potential is $V = \frac{U}{q_o}$

Electric Potential, final

- The potential is a scalar quantity
  - Since energy is a scalar
- As a charged particle moves in an electric field, it will experience a change in potential

$$\Delta V = \frac{\Delta U}{q_o} = -\int_A^B \mathbf{E} \cdot d\mathbf{s}$$

Work and Electric Potential

- Assume a charge moves in an electric field without any change in its kinetic energy
- The work performed on the charge is

$$W = \Delta V = q\,\Delta V$$

Units

- 1 V = 1 J/C
  - V is a volt
  - It takes one joule of work to move a 1-coulomb charge through a potential difference of 1 volt
- In addition, 1 N/C = 1 V/m
  - This indicates we can interpret the electric field as a measure of the rate of change with position of the electric potential

Electron-Volts

- Another unit of energy that is commonly used in atomic and nuclear physics is the electron-volt
- One ***electron-volt*** is the energy a charge-field system gains or loses when a charge of magnitude *e* (an electron or a proton) is moved through a potential difference of 1 volt
  - $1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$

Potential Difference in a Uniform Field

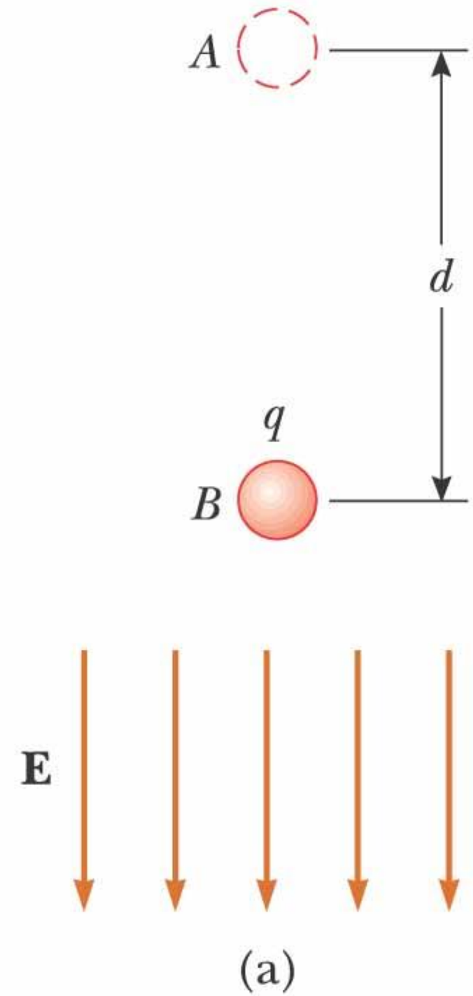
- The equations for electric potential can be simplified if the electric field is uniform:

$$V_B - V_A = \Delta V = -\int_A^B \mathbf{E} \cdot d\mathbf{s} = -E\int_A^B d\mathbf{s} = -Ed$$

- The negative sign indicates that the electric potential at point *B* is lower than at point *A*

Energy and the Direction of Electric Field

- When the electric field is directed downward, point *B* is at a lower potential than point *A*
- When a positive test charge moves from *A* to *B*, the charge-field system loses potential energy

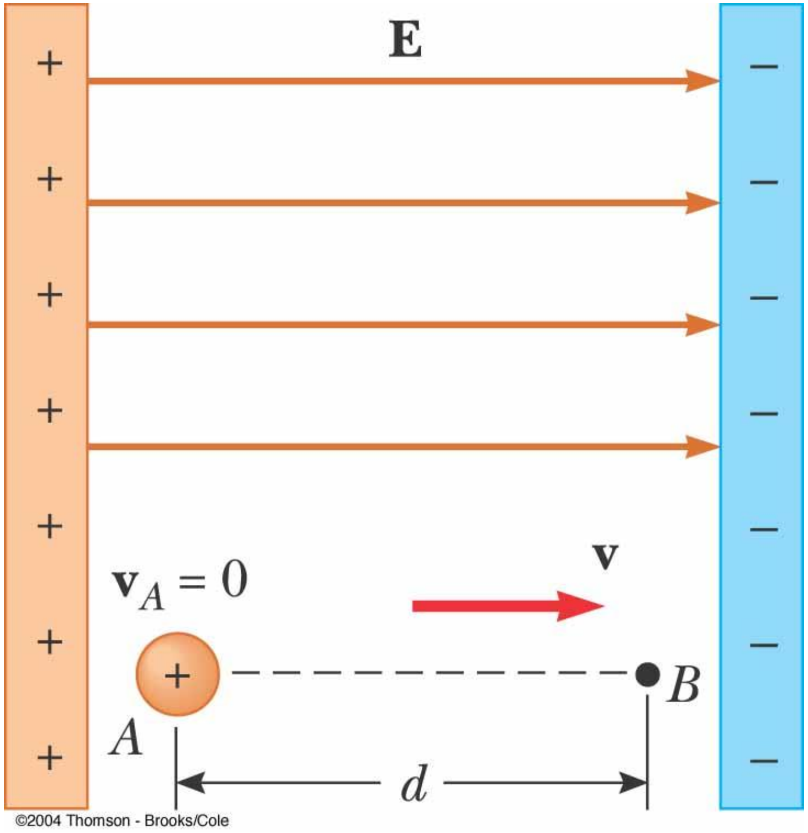


Directions, cont.

- If q_o is negative, then ΔU is positive
- A system consisting of a negative charge and an electric field *gains* potential energy when the charge moves in the direction of the field
  - In order for a negative charge to move in the direction of the field, an external agent must do positive work on the charge

Charged Particle in a Uniform Field, Example

- A positive charge is released from rest and moves in the direction of the electric field
- The change in potential is negative
- The change in potential energy is negative
- The force and acceleration are in the direction of the field

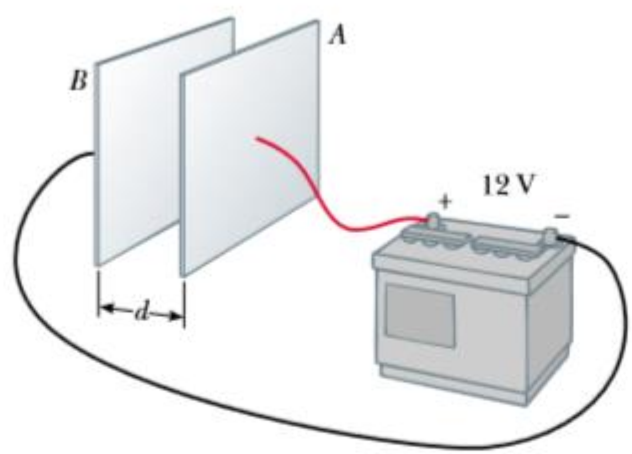


EXAMPLE 25.1 The Electric Field Between Two Parallel Plates of Opposite Charge

A battery produces a specified potential difference between conductors attached to the battery terminals. A 12-V battery is connected between two parallel plates, as shown in Figure 25.4. The separation between the plates is $d = 0.30$ cm, and we assume the electric field between the plates to be uniform.

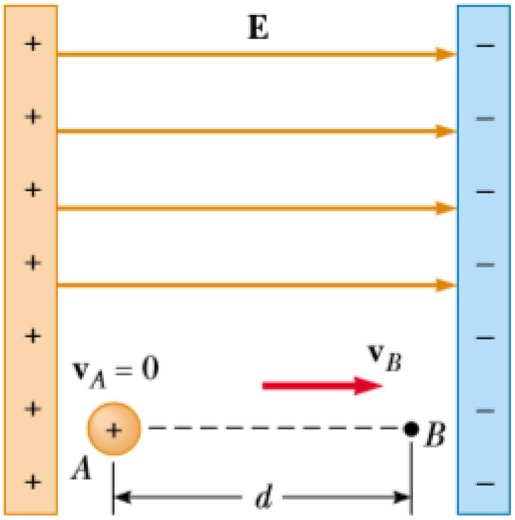
Find the magnitude of the elec- tric field between the plates.

$$E = \frac{|V_B - V_A|}{d} = \frac{12\text{ V}}{0.30 \times 10^{-2}\text{ m}} = 4.0 \times 10^3 \text{ V/m}$$



EXAMPLE 25.2 Motion of a Proton in a Uniform Electric Field

A proton is released from rest in a uniform electric field that has a magnitude of 8.0×10^4 V/m and is directed along the positive x axis (Fig. 25.5). The proton undergoes a displacement of 0.50 m in the direction of **E**. (a) Find the change in electric potential between points A and B.



EXAMPLE 25.2 Motion of a Proton in a Uniform Electric Field

$$\Delta V = -Ed = -(8.0 \times 10^4\ \text{V/m})(0.50\ \text{m})$$

$$= -4.0 \times 10^4\ \text{V}$$

(b) Find the change in potential energy of the proton for this displacement.

Solution

$$\Delta U = q_0\,\Delta V = e\,\Delta V$$

$$= (1.6 \times 10^{-19}\ \text{C})(-4.0 \times 10^4\ \text{V})$$

$$= -6.4 \times 10^{-15}\ \text{J}$$

EXAMPLE 25.2 Motion of a Proton in a Uniform Electric Field

The negative sign means the potential energy of the proton decreases as it moves in the direction of the electric field. As the proton accelerates in the direction of the field, it gains kinetic energy and at the same time loses electric potential energy (because energy is conserved).

Exercise Use the concept of conservation of energy to find the speed of the proton at point B.

Answer 2.77×10^6 m/s.

Question 25.1

How much work is done (by a battery, generator, or some other source of electrical energy) in moving Avogadro's number of electrons from an initial point where the electric potential is 9.00 V to a point where the potential is -5.00 V?

Question 25.1- Solution

$\Delta V = -14.0 \text{ V}$ and $Q = -N_A e = -(6.02 \times 10^{23})(1.60 \times 10^{-19}) = -9.63 \times 10^4 \text{ C}$

$\Delta V = \frac{W}{Q}$, so $W = Q\Delta V = (-9.63 \times 10^4 \text{ C})(-14.0 \text{ J/C}) = \boxed{1.35 \text{ MJ}}$