Imam Abdulrahman Bin Faisal University
College of Computer Science & IT
Department of CS
Term 2191

Welcome
to
PHYS 212: Physics

Chapter#24

Electric Potential

Topics

- Electric potential.
- Electric potential energy.
- Equipotential surfaces.

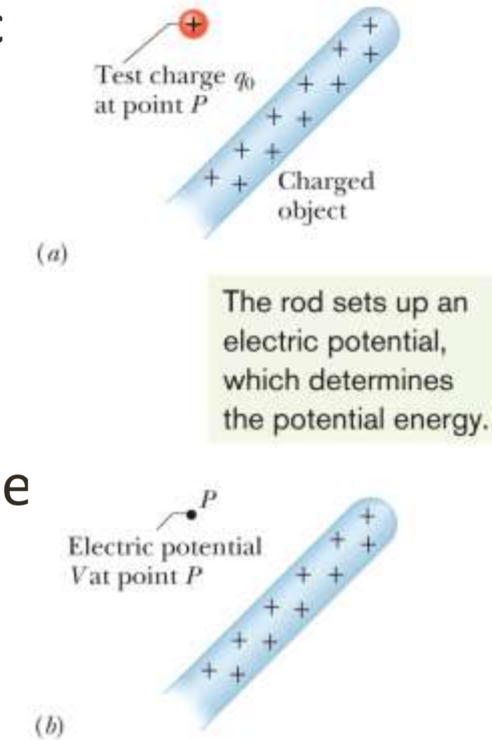
24-1 Electric Potential

The electric potential **V** at a point **P** in the electric field of a charged object is

$$V = \frac{-W_\infty}{q_0} = \frac{U}{q_0}$$

where $\boldsymbol{W_\infty}$ is the work that would be done by the electric force on a positive test charge $\boldsymbol{q_0}$ were it brought from an infinite distance to ***P***, and ***U*** is the electric potential energy that would then be stored in the test charge–object system.

If a particle with charge ***q*** is placed at a point where the electric potential of a charged object is ***V***, the electric potential energy ***U*** of the particle–object system is $U = qV$.



(a) A test charge has been brought in from infinity to point P in the electric field of the rod.

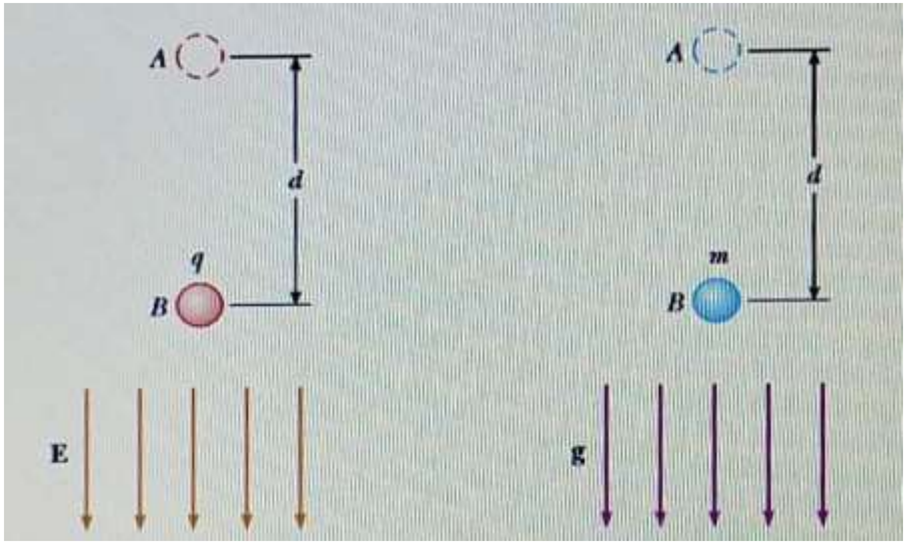
(b) We define an electric potential V at P based on the potential energy of the configuration in (a).

24-1 Electric Potential Difference

❖ The potential difference $\Delta V = V_B - V_A$ between two points **A** and **B** in an electric field is defined as the change in potential energy of the system when a test charge is moved between the points divided by the test charge q_o.

$$\Delta V = \frac{\Delta U}{q_o} = -\int_A^B E.ds$$

$$\Delta V = -E\int_A^B ds = -Ed$$



❖ The negative sign indicates that the electric potential at point **B** is lower than at point **A**; that is, $V_B < V_A$.

❖ **Electric field lines always point in the direction of decreasing electric potential.**

24-1 Electric Potential Energy

Change in Electric Potential: If the particle moves through a potential difference ***ΔV***, the change in the electric potential energy is

$$\Delta U = q\,\Delta V = q(V_f - V_i).$$

Work by the Field: The work **W** done by the electric force as the particle moves from ***i*** to ***f***:

$$W = -\Delta U = -q\,\Delta V = -q(V_f - V_i).$$

Conservation of Energy: If a particle moves through a change ***ΔV*** in electric potential without an applied force acting on it, applying the conservation of mechanical energy gives the change in kinetic energy as

$$\Delta K = -q\,\Delta V = -q(V_f - V_i).$$

Work by an Applied Force: If some force in addition to the electric force acts on the particle, we account for that work

$$\Delta K = -\Delta U + W_{app} = -q\,\Delta V + W_{app}.$$

Problem-1:

Suppose that in a lightning flash the potential difference between a cloud and the ground is $1.0 \text{ X}10^9$ V and the quantity of charge transferred is 30 C.

(a) What is the change in energy of that transferred charge?

Answer:

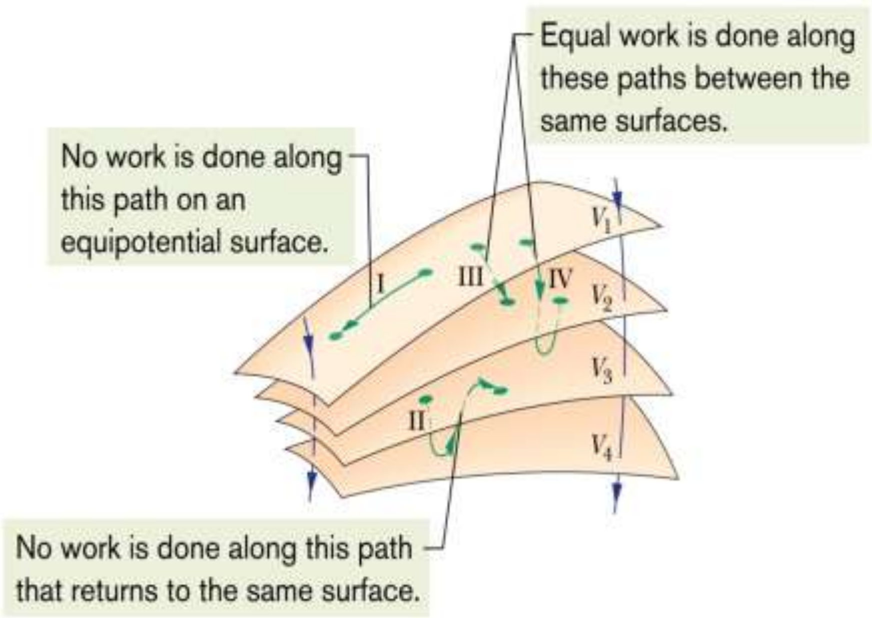
$$\Delta U = 3.0 \times 10^{10} \text{ J}$$

24-2 Equipotential Surfaces

The name **equipotential surface** is given to any surface consisting of a continuous distribution of points having the same electric potential.

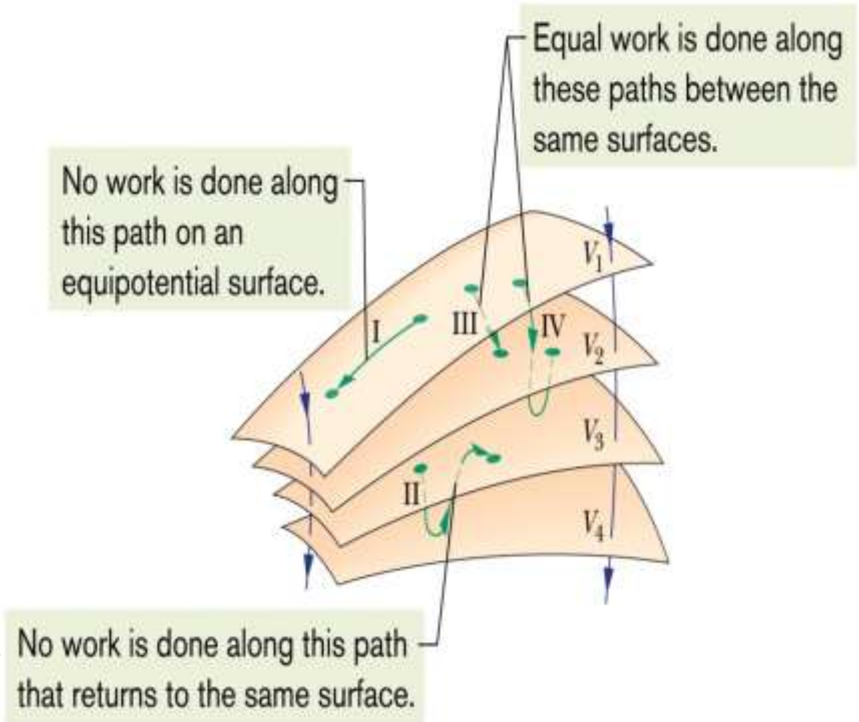
•**Figure** shows a family of equipotential surfaces associated with the electric field due to some distribution of charges.

•The work done by the electric field on a charged particle as the particle moves from one end to the other of paths **I** and **II** is zero because each of these paths begins and ends on the same equipotential surface and thus there is no net change in potential.



Equipotential Surfaces

The work done as the charged particle moves from one end to the other of paths **III** and **IV** is not zero but has the same value for both these paths because the initial and final potentials are the same for the two paths; that is, paths **III** and **IV** connect the same pair of equipotential surfaces.



Problem-2:

When an electron moves from *A to B along an electric field line in* Fig. 24-34, the electric field does 3.94 X 10^{-19} J of work on it. What are the electric potential differences

(a) $V_B - V_A$, (b) $V_C - V_A$, and (c) $V_C - V_B$?

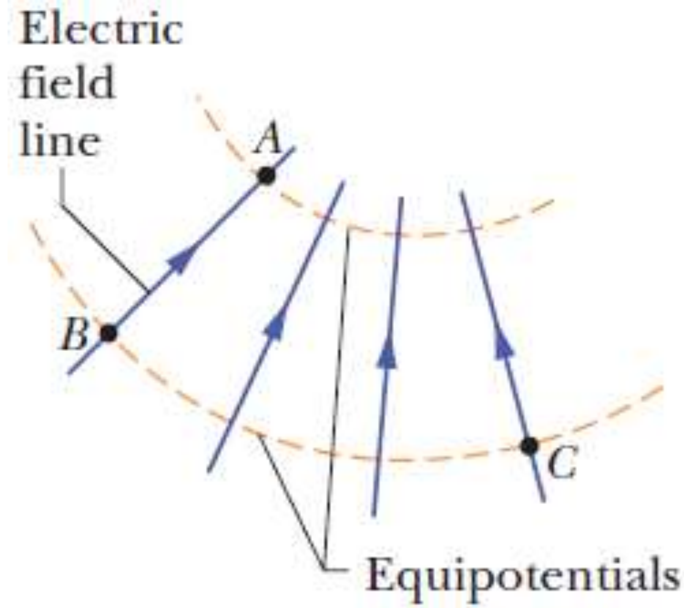


Figure 24-34 Problem 6.

Answer:

(a) $V_B - V_A = \Delta U/q = -W/(-e) = -(3.94 \times 10^{-19}\ \text{J})/(-1.60 \times 10^{-19}\ \text{C}) = 2.46\ \text{V}$.

(b) $V_C - V_A = V_B - V_A = 2.46\ \text{V}$.

(c) $V_C - V_B = 0$ (since C and B are on the same equipotential line).

Problem-3: A battery produces a specified potential difference ΔV between conductors attached to the battery terminals. A 12-V battery is connected between two parallel plates, as shown in Figure 25.5. The separation between the plates is $d = 0.30$ cm, and we assume the electric field between the plates to be uniform. (This assumption is reasonable if the plate separation is small relative to the plate dimensions and if we do not consider locations near the plate edges.) Find the magnitude of the electric field between the plates.

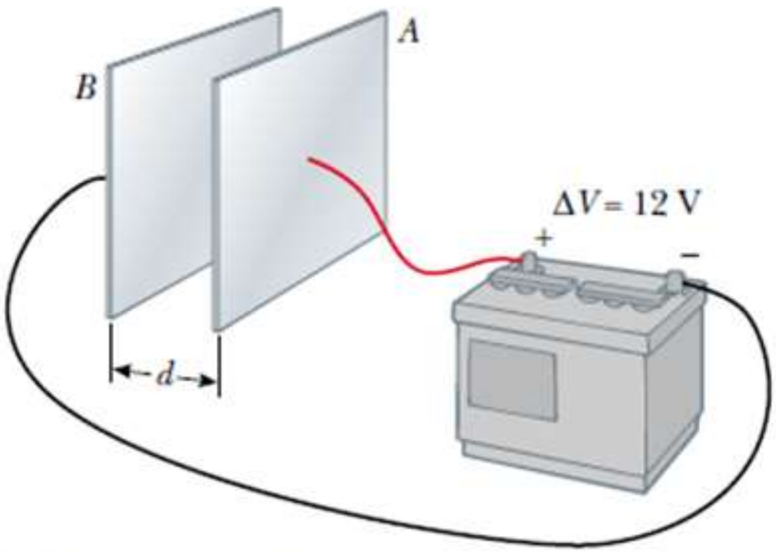


Figure 25.5 (Example 25.1) A 12-V battery connected to two parallel plates. The electric field between the plates has a magnitude given by the potential difference ΔV divided by the plate separation d.

Solution The electric field is directed from the positive plate (A) to the negative one (B), and the positive plate is at a higher electric potential than the negative plate is. The potential difference between the plates must equal the potential difference between the battery terminals. We can understand this by noting that all points on a conductor in equilibrium are at the same electric potential[1]; no potential difference exists between a terminal and any portion of the plate to which it is connected. Therefore, the magnitude of the electric field between the plates is, from Equation 25.6,

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

The configuration of plates in Figure 25.5 is called a *parallel-plate capacitor*, and is examined in greater detail in Chapter 26.

Electron-volts

Electron-volts: It is defined as the work required to move a single elementary charge ***e*** *(such as that of an electron or proton)* through a potential difference ΔV of exactly one volte.

$$W = q\Delta V$$

1 eV = (1.602 X 10^{-19} C) (1 J/C) = 1.602 X 10^{-19} Joule

Example 25.2 Motion of a Proton in a Uniform Electric Field

Interactive

A proton is released from rest in a uniform electric field that has a magnitude of 8.0×10^4 V/m (Fig. 25.6). 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.

Solution Because the positively charged proton moves in the direction of the field, we expect it to move to a position of lower electric potential. From Equation 25.6, we have

$$\Delta V = -Ed = -(8.0 \times 10^4 \text{ V/m})(0.50 \text{ m}) = \boxed{-4.0 \times 10^4 \text{ V}}$$

(B) Find the change in potential energy of the proton–field system for this displacement.

Solution Using Equation 25.3,

$$\begin{aligned}\Delta U &= q_0\,\Delta V = e\,\Delta V \\ &= (1.6 \times 10^{-19}\text{ C})(-4.0 \times 10^4\text{ V}) \\ &= \boxed{-6.4 \times 10^{-15}\text{ J}}\end{aligned}$$

The negative sign means the potential energy of the system decreases as the proton 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 the system loses electric potential energy.

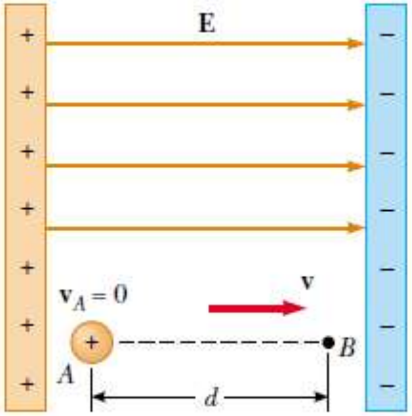


Figure 25.6 (Example 25.2) A proton accelerates from A to B in the direction of the electric field.