Ch 4: Potential Difference and Potential Energy

Ch 25 on Book

Lecture Contents

- •Electric Potential Energy.
- •Potential Difference.
- •Potential Difference in a Uniform Electric Field.
- •Electric Potential and Potential Energy due to Point Charges

Potential Difference and Electric Potential.

- q_0 is placed in *E.*
- Force on $q_0 = E\, q_0$.
- q_0 moved a tiny distance *ds*.
- Work done by *E* on $q_0 = F\, ds = E\, q_0\, ds.$
- Potential energy of the system (charge and field) = $dU = - E\, q_0\, ds.$
- If the charge moved a finite distance from A to B, then change in potential energy can be expressed as:

$$\Delta U = -q_0 \int_A^B E \bullet ds$$

Potential Difference and Electric Potential.

- Electric force ($E\ q_0$) is conservative, then the integral is not function of path between the points.

$$\Delta U = -q_0 \int_A^B E \bullet ds$$

- The electric potential is the potential energy per unit charge.

$$V_2 - V_1 = \frac{\Delta U}{q_0} = -\int_A^B E \bullet ds$$

Units: J/C = volt

- Electric potential is independent of the test charge q_0.
- It is found on every point in electric field.

Potential difference should not be confused with the difference in potential energy.

In potential difference, it is not necessary for a charge to be present between the points, in difference in potential energy a charge should be moved between the points.

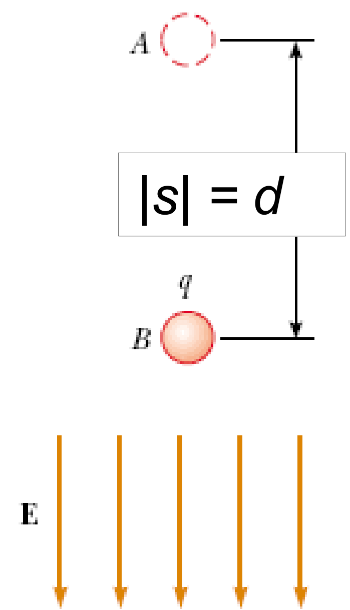
Potential Difference in a uniform Electric Field.

•Uniform electric field *E* , what is ΔV ?

•The distance between the two points (*A, B*) *s* (parallel to *E*.

•ΔV is given by:

$$V_B - V_A = \Delta V = -\int_A^B E \bullet ds$$



•*E* and *s* is on the same direction ($\theta = 0$) then,

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

What does it mean?

•Potential at *B* is less than at *A* (why?).

•Electric field lines always pointed toward decreasing electric potential.

•What if one wants to calculate the change in potential energy of a charge (q_0) moves from *A* to *B*?

$$\Delta U = q_0 \, \Delta V = -q_0 E d$$

•q_0 positive, then ΔU is negative, (system of charge and the field loses electric potential energy. i.e. the field does work on the charge to move it in the direction of electric field. and vice versa.

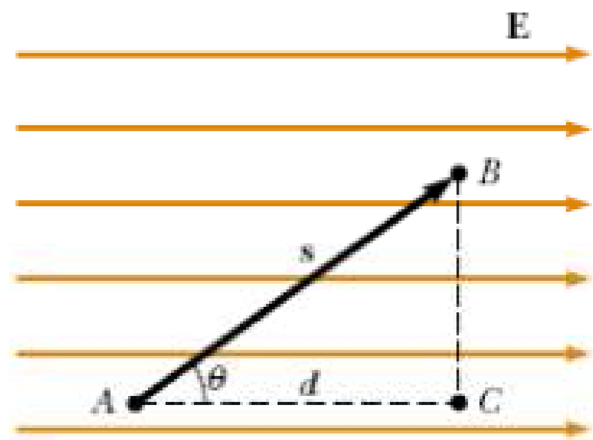
General View

- Electric field makes angle θ with *s*.

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

$\boxed{E \bullet s}$ is a dot product $= E\, s \cos\theta$

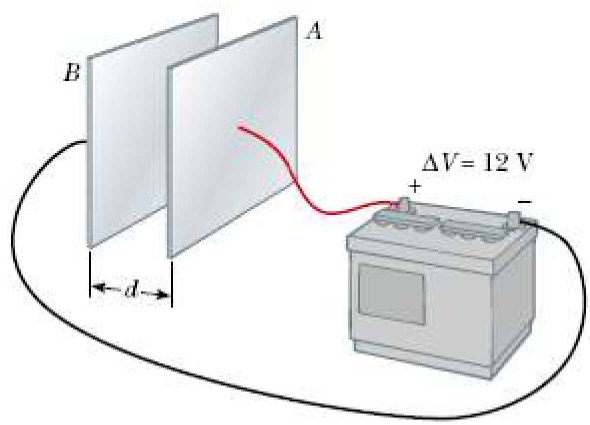
- $s \cos \theta = d$ (distance parallel to the electric field lines).
- This means $V_B - V_A = - E\, d$
- $V_C - V_A = ?$ ⇨ $= - E\, d$,
- *This means that* $V_B = V_C$.
- And the line joining points B and C is of the same electric potential (equipotential line)



Equipotential line is perpendicular to *E.*

Example 1

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 below. The separation between the plates is d = 0.3 cm, and we assume the electric field between the plates to be uniform. Find the magnitude of the electric field between the plates.



$$E = \frac{|V_B - V_A|}{d}$$

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

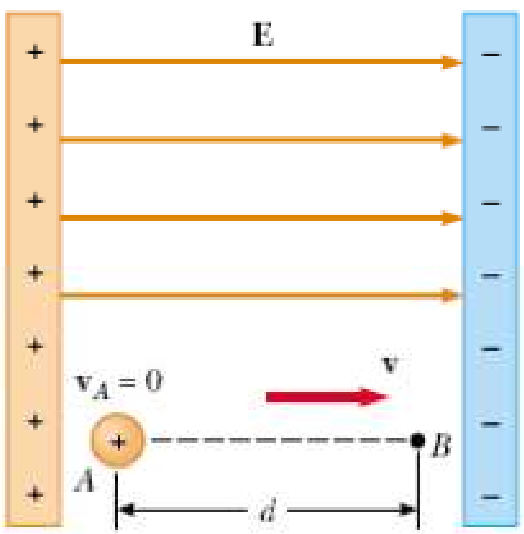
Example 2

A proton is released from rest in a uniform electric field that has a magnitude of 8 x 10^4 V/m. The proton undergoes a displacement of 0.5 m in the direction of E.

A. Find the change in electric potential between points *A* and *B*.

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

C. Find the speed of the proton after completing the 0.50 m displacement in the electric field.



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

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

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

$$\Delta K + \Delta U = 0 \qquad (\tfrac{1}{2}mv^2 - 0) + e\,\Delta V = 0$$

$$v = \sqrt{\frac{-(2e\Delta V)}{m}}$$

$$= \sqrt{\frac{-2(1.6 \times 10^{-19}\ \mathrm{C})(-4.0 \times 10^4\ \mathrm{V})}{1.67 \times 10^{-27}\ \mathrm{kg}}}$$

$$= \boxed{2.8 \times 10^6\ \mathrm{m/s}}$$