Lecture 16 (12-1)

Tuesday, March 30, 2021 11:45 AM

Ch. 25 / Electric Potential

25.1 Electric Potential and Potential Difference

When a point charge q in $\vec{E} \Rightarrow \vec{F_e} = q\vec{E}$

If q is free to move $\rightarrow \vec{E}$ will do a work on q

if q moves a displacement $\vec{ds}$

$\Rightarrow$ Work done $\Rightarrow W_{int} = \vec{F_e} \cdot \vec{ds}$

From Physics 1:

$$W_c = W_{int} = -\Delta U = U_i - U_f$$

$$W_{ext} = +\Delta U = U_f - U_i$$

$\Rightarrow W_{int} = -\Delta U$

$-dU = W_{int} = \vec{F_e} \cdot \vec{ds} \Rightarrow dU = -\vec{F_e} \cdot \vec{ds}$

$\Rightarrow dU = -q\vec{E} \cdot \vec{ds}$

Integrate $\Rightarrow \int_A^B dU = -q \int_A^B \vec{E} \cdot \vec{ds}$

$$\boxed{\Delta U = U_B - U_A = -q \int_A^B \vec{E} \cdot \vec{ds}} \rightarrow (*)$$

$\Rightarrow$ The change in electric potential energy of the system

V ... electric potential (or potential) ...

$V \rightarrow$ electric potential (or potential)

$V = \frac{U}{q} \rightarrow \Delta V = \frac{\Delta U}{q}$

$\Rightarrow$ From eqn (*) $\Rightarrow$ $\boxed{\Delta V = \frac{\Delta U}{q} = V_B - V_A = -\int_A^B \vec{E} \cdot \vec{ds}}$ $\rightarrow$ (**)

$\rightarrow$ Potential difference

- The work done needed to move a charge q by an external agent at constant velocity:

$$\boxed{W = +\Delta U = q \, \Delta V}$$

Units of $\Delta V \equiv \frac{J}{C} \equiv V \rightarrow$ Volt

electron-volt $\equiv eV = ?$

$= (1.6 \times 10^{-19} \, C)(1 \, V)$

$= 1.6 \times 10^{-19} \, C \cdot V$

$$\boxed{1 \, eV = 1.6 \times 10^{-19} \, J}$$

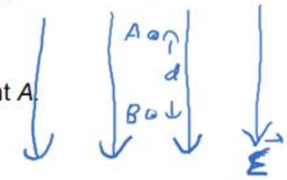
From eqn (**) $\Rightarrow$ another unit of $\vec{E} \Rightarrow V/m$

Potential Difference in a Uniform Field (25.2)

The equations for electric potential between two points A and B can be simplified if the electric field is uniform:

$\vec{E} \parallel d\vec{s} \Rightarrow \vec{E}\cdot d\vec{s} = E\,ds$

$$(**) \leftarrow \boxed{V_B - V_A = \Delta V = -\int_A^B \vec{\mathbf{E}} \cdot d\vec{\mathbf{s}}} = -E\int_A^B d\mathbf{s} = -Ed$$



The displacement points from A to B and is parallel to the field lines.

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

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

$$V_B - V_A < 0 \Rightarrow V_B < V_A$$

Energy and the Direction of Electric Field

When the electric field is directed downward, point *B* is at a lower potential than point *A*.

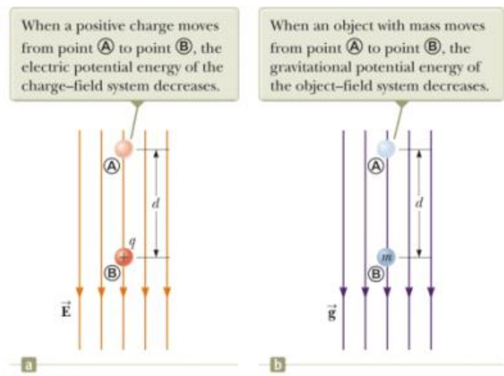
When a positive test charge moves from *A* to *B*, the charge-field system loses potential energy.

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

$$\Delta U = q\,\Delta V = q(-Ed) = -qEd$$

$\Rightarrow$ If q is $(+) \Rightarrow \Delta U < 0$ $(-)$

If q is $(-) \Rightarrow \Delta U > 0$ $(+)$



$$\Delta U + \Delta K = 0 \Leftrightarrow E_i = E_f$$

More About Directions

A system consisting of a positive charge and an electric field **loses** electric potential energy when the charge moves in the direction of the field.

- An electric field does work on a positive charge when the charge moves in the direction of the electric field.

The charged particle gains kinetic energy and the potential energy of the charge-field system decreases by an equal amount.

- Another example of Conservation of Energy

$$W_{int} = -\Delta U$$
$$\Rightarrow \Delta U = -W_{int}$$

Directions, cont.

If q_0 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.

$$W_{ext} = +\Delta U$$

$$\Delta V = -Ed$$

$$\Delta U = q\Delta V = -qEd$$

$$+q \Rightarrow \Delta U < 0$$