Summary of chapter 24

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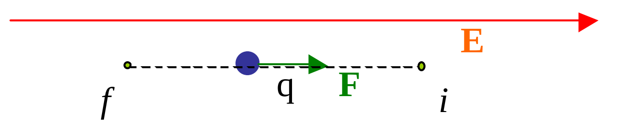
1. An *electric force* F acts on a point charge q in an external *electric field* E as shown below.



This force is conservative $\Rightarrow$ ***W = – DU***

2. We define the electric potential V at a point in the electric field as the potential energy per unit charge, that is

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

So the *electric potential difference* between points *i* and *f* is

$$\Delta V = V_f - V_i = \frac{\Delta U}{q}$$

The unit of the potentials energy is Joule and the unit of the electric potential is Joule/Coulomb = Volt.

The potential is a scalar.

Another unit of potential energy is used, that is electron-volt (eV);

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

The work done by an external agent in moving the charge from ***i*** to ***f*** is equal to the negative of the work done by the electric force; therefore;

$W = -q\Delta V$ **(work done by the electric force)**

$W_{app} = q\,\Delta V$ **(work done by the applied force)**

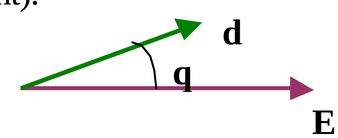
3. The electric potential difference can be calculated from

$$\Delta V = V_f - V_i = -\int \vec{E}\cdot d\vec{s}$$

If E is ***uniform***, then

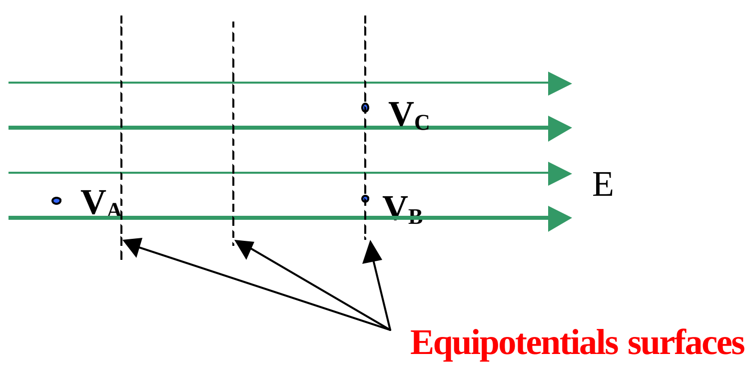
$$\Delta V = -\vec{E}\cdot\vec{d} = -E\,d\cos\theta$$

where θ is the angle between E and d (displacement).



Special cases:

- If $\theta = 0$, $\Delta V = V_f - V_i = -E\,d < 0$ ***The potential decreases.***
- If $\theta = 180^o$, $\Delta V = V_f - V_i = E\,d > 0$ ***The potential increases.***
- If $\theta = 90^o$, $\Delta V = V_f - V_i = 0$ ***The potential remains constant.***



$\Rightarrow$ $V_A > V_B = V_C$

4. The change in electric potential energy, ΔU, of a charge moving from point ***i*** to point ***f*** in a uniform electric field is given by;

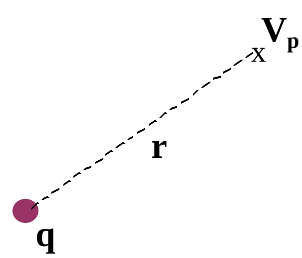
$$\Delta U = q(V_f - V_i) = -q\ E\ d\ \cos q$$

- ***We can see from this formula that if q is positive, DU will be negative Þ a positive charge will lose potential energy when it moves in the direction of the electric field (q = 0) and at the same time will gain kinetic energy, <u>because the total energy is conserved</u>.***

- ***On the other hand, if the charge is negative, DU will be positive Þ a negative charge will gain potential energy when it moves in the direction of the electric field (q = 0) and at the same time will lose kinetic energy.***

5. The electric potential due to a point charge q a distance r away from the point charge is

$$V_p = k\frac{q}{r}$$



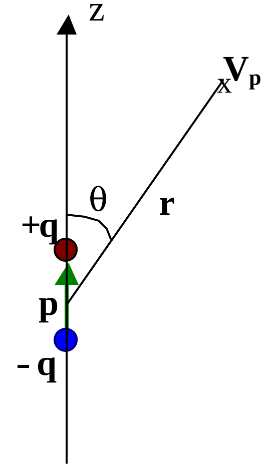
If q > 0, then V > 0, and if q < 0, then V < 0.

Note: ***The electric potential is taken to be zero at infinity.***

6. The electric potential at a point p due to a group of charges; q_1, q_2, q_3, … , q_n is given by

$$V_p = k\left(\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3} + \ldots + \frac{q_n}{r_n}\right)$$

7. The potential due to an electric dipole is



$$V_p = k\frac{p\cos\theta}{r^2}$$

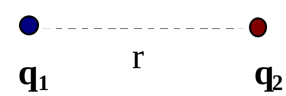
$p = q\,d$ *is the dipole moment.*

8. The electric field E can be evaluated if the electric potential V is known;

$$E_x = -\frac{\partial V}{\partial x};\ E_y = -\frac{\partial V}{\partial y};\ E_z = -\frac{\partial V}{\partial z}$$

9. The potential energy of a pair of charges separated by a distance r is given by;

$$U = k\frac{q_1 q_2}{r}$$



Important: THIS ENERGY REPRESENTS THE WORK done by an external agent to assemble the charges **from infinity** to their position at r.

To assemble three charges; q, q_2, q_3, the potential energy (or work required) will be;

$$U = k\left(\frac{q_1 q_2}{r_{12}} + \frac{q_1 q_3}{r_{13}} + \frac{q_2 q_3}{r_{23}}\right)$$

If $U > 0$, an external agent do positive work to assemble the charges, and if $U < 0$, the electric field does the work.

10. The electric potential of a charged isolated conductor

- The surface of a charged conductor is an ***equipotential surface***.

- Since the electric field inside a conductor is zero, ***the potential*** is therefore ***constant inside a charged conductor*** and equal to that at the surface.

- For a conducting sphere of radius ***R*** and charge **q**, the electric potential is

  - $V_{in} = \frac{kq}{R}$ (**inside and on the surface of the conductor**)

  - $V_{out} = \frac{kq}{r}$ (outside)