# Ch 4: Potential Difference and Potential Energy – Part 2

Ch 25 on Book

http://fac.ksu.edu.sa/fayalalhusan/course/91769

# Electric potential and potential energy due to point charges:

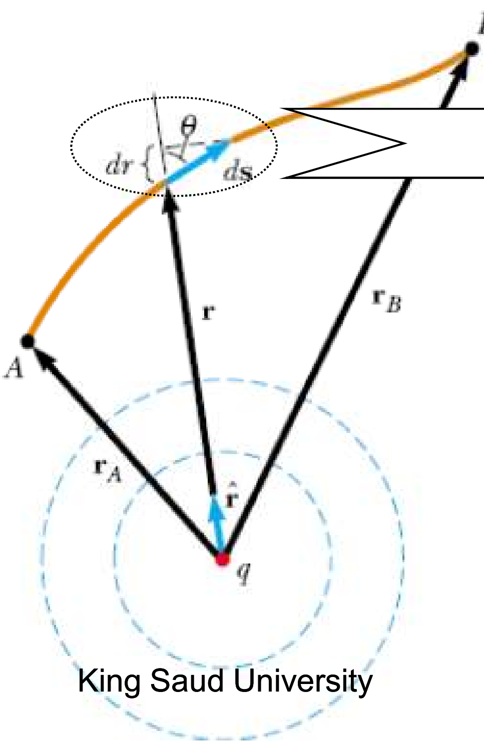
The electric potential between two arbitrary points A and B:

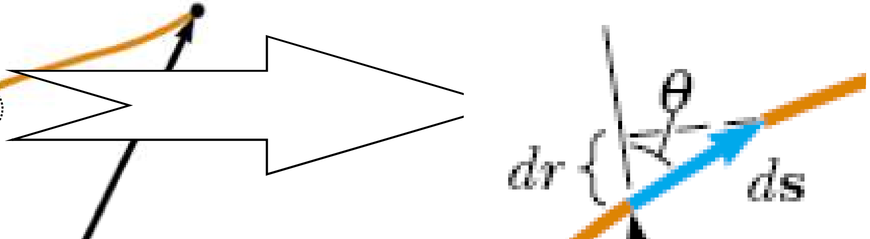
$$V_B - V_A = -\int_A^B \mathbf{E}\cdot d\mathbf{s}$$

field due to a point charge is given by: $\mathbf{E} = k_e q \hat{\mathbf{r}}/r^2$

$\widehat{r}$ is a unit vector directed from the charge to the point of concern.

Then the quantity $E \bullet ds$ can be expressed as:




$$\mathbf{E}\cdot d\mathbf{s} = k_e \frac{q}{r^2}\,\hat{\mathbf{r}}\cdot d\mathbf{s}$$

$$\widehat{r} \bullet ds = ds\cos\theta = dr$$

$$\mathbf{E}\cdot d\mathbf{s} = (k_e q/r^2)\,dr$$

$$V_B - V_A = -k_e q \int_{r_A}^{r_B} \frac{dr}{r^2} = \frac{k_e q}{r}\Bigg]_{r_A}^{r_B}$$

$$V_B - V_A = k_e q\left[\frac{1}{r_B} - \frac{1}{r_A}\right]$$

# Cont.

That means that E.ds is independent of the path.

It is customary to choose the reference point of electric field to be zero at infinity [ i.e. V = 0 when r→∞

the electric potential created by point charge at any distance *r* from the charge is

$$V = k_e \frac{q}{r}$$

If there is more than one charge

$$V = k_e \sum_i \frac{q_i}{r_i}$$

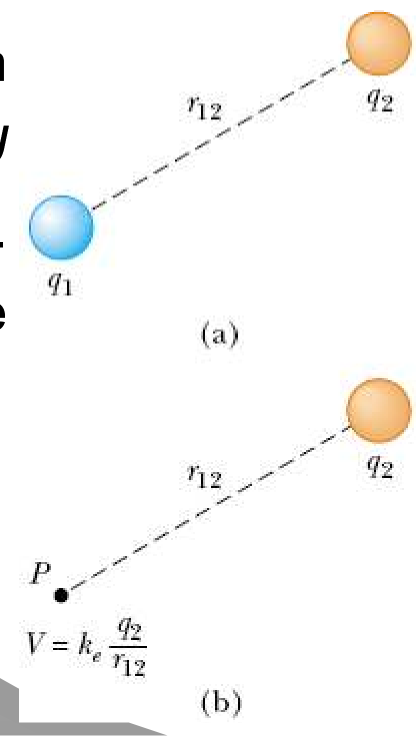
# Potential energy of system of particles

We now consider the potential energy of a system of two charged particles.

If $V_2$ is the electric potential at a point $P$ due to charge $q_2$, then the work an external agent must do to bring a second charge $q_1$ from infinity to $P$ without acceleration is $q_1 V_2$.

This work represents a transfer of energy into the system and the energy appears in the system as potential energy $U$ when the particles are separated by a distance $r_{12}$. Therefore, we can express the potential energy of the system as:

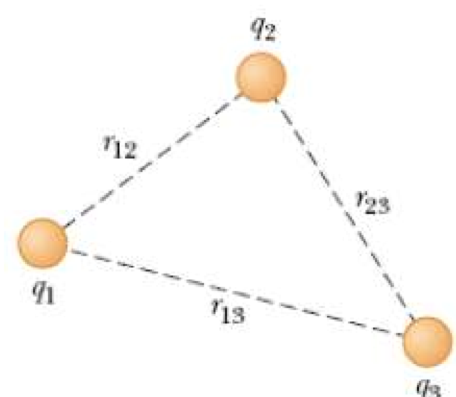
$$U = k_e \frac{q_1 q_2}{r_{12}}$$



# Potential energy of system of particles

If the system consists of more than two charged particles, we can obtain the total potential energy by calculating *U* for every pair of charges and summing the terms algebraically. *U* for the three charges system can be expressed as:

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



# Example

A charge $q_1$ = 2.00 $\mu$C is located at the origin, and a charge $q_2$ = – 6.00 $\mu$C is located at (0, 3.00) m, as shown in the Figure below.

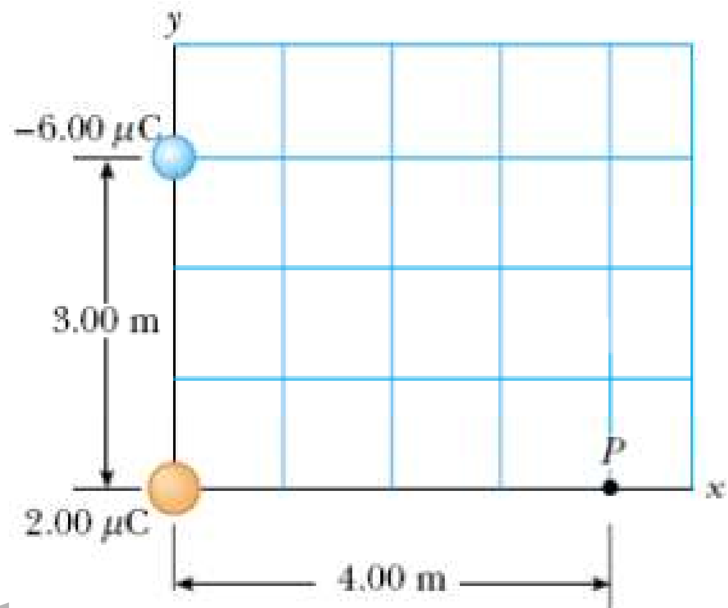
Find the total electric potential due to these charges at the point *P*, whose coordinates are (4.00, 0) m.

Find the change in potential energy of the system of two charges plus a charge $q_3$=3.00 $\mu$C as the latter charge moves from infinity to point *P*

$$V_P = k_e\left(\frac{q_1}{r_1} + \frac{q_2}{r_2}\right)$$

$$V_P = (8.99 \times 10^9\ \mathrm{N\cdot m^2/C^2}) \times \left(\frac{2.00 \times 10^{-6}\ \mathrm{C}}{4.00\ \mathrm{m}} - \frac{6.00 \times 10^{-6}\ \mathrm{C}}{5.00\ \mathrm{m}}\right)$$

$$= \boxed{-6.29 \times 10^3\ \mathrm{V}}$$



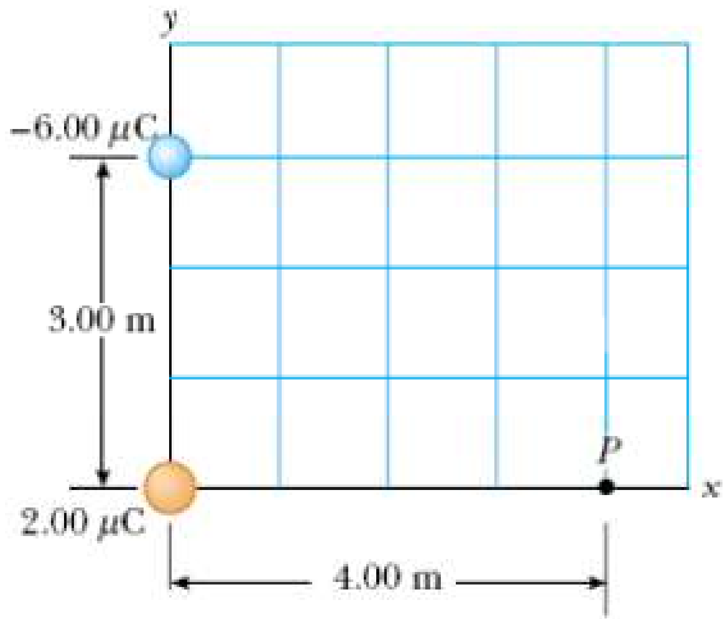
**Example:** A charge $q_1$ = 2.00 $\mu$C is located at the origin, and a charge $q_2$ = – 6.00 $\mu$C is located at (0, 3.00) m, as shown in the Figure below.

Find the total electric potential due to these charges at the point *P*, whose coordinates are (4.00, 0) m.

Find the change in potential energy of the system of two charges plus a charge $q_3$=3.00 $\mu$C as the latter charge moves from infinity to point *P*

$$\Delta U = q_3 V_P - 0 = (3.00 \times 10^{-6}\ \text{C})(-6.29 \times 10^3\ \text{V})$$

$$= \boxed{-1.89 \times 10^{-2}\ \text{J}}$$




had asked to find the change in potential energy when *all three* charges start out infinitely far apart and are then brought to the positions in Figure 25.12b, we would need to calculate the change as follows, using Equation 25.14:

$$U = k_e\left(\frac{q_1q_2}{r_{12}} + \frac{q_1q_3}{r_{13}} + \frac{q_2q_3}{r_{23}}\right)$$

$$= (8.99 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)$$

$$\times \left(\frac{(2.00 \times 10^{-6}\ \text{C})(-6.00 \times 10^{-6}\ \text{C})}{3.00\ \text{m}} + \frac{(2.00 \times 10^{-6}\ \text{C})(3.00 \times 10^{-6}\ \text{C})}{4.00\ \text{m}} + \frac{(3.00 \times 10^{-6}\ \text{C})(-6.00 \times 10^{-6}\ \text{C})}{5.00\ \text{m}}\right)$$

$$= -5.48 \times 10^{-2}\ \text{J}$$