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General Physics II

Electrostatic: Principles & Applications

Lecture (12): Discussion on Electric Potential

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Electric Potential

1. Definition of electric potential difference
2. The Equipotential surfaces
3. Electric Potential and Electric Field
4. Potential difference due to a point charge
5. The potential due to a point charge
6. Electric Potential Energy
7. Calculation of E from V
8. Problems

في هذه الفصل سوف نتعلم كيف يمكننا التعبير عن التأثير الكهربي في الفراغ المحيط بشحنة أو أكثر بواسطة كمية قياسية تسمى الجهد الكهربي The electric potential. وحيث أن الجهد الكهربي كمية قياسية وبالتالي فسيكون التعامل معه أسهل في التعبير عن التأثير الكهربي من المجال الكهربي.

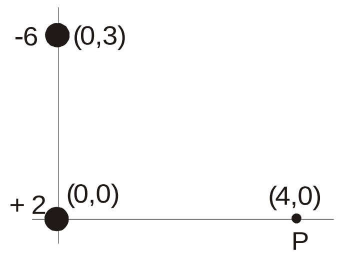
Example 1

Two charges of 2μC and -6μC are located at positions (0,0) m and (0,3) m, respectively as shown in the figure.

(i) Find the total electric potential due to these charges at point (4,0) m.

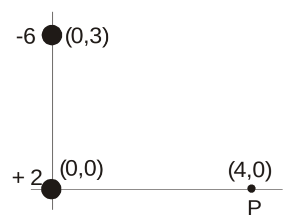
(ii) (ii) How much work is required to bring a 3μC charge from ∞ to the point *P*?

(iii) (iii) What is the potential energy for the three charges?



Solution

(i) the total electric potential due to these charges …….



$$V_p = V_1 + V_2$$

$$V = \frac{1}{4\pi\varepsilon_o}\left[\frac{q_1}{r_1} + \frac{q_2}{r_2}\right]$$

$$V = 9\times10^{9}\left[\frac{2\times10^{-6}}{4} - \frac{6\times10^{-6}}{5}\right] = -6.3\times10^{3}\ volt$$

(ii) the work required is given by

$$W = q_3\, V_p = 3 \times 10^{-6} \times -6.3 \times 10^{3} = -18.9 \times 10^{-3}\ \text{J}$$

The -ve sign means that work is done by the charge for the movement from ∞ to *P*.

(iii) **The potential energy is given by**

$$U = U_{12} + U_{13} + U_{23}$$

$$U = k\left[\frac{(2\times10^{-6})(-6\times10^{-6})}{3} + \frac{(2\times10^{-6})(3\times10^{-6})}{4} + \frac{(-6\times10^{-6})(3\times10^{-6})}{5}\right]$$

$$\therefore U = -5.5\times10^{-2}\ Joule$$

Example 2

A particle having a charge q=3×10^{-9}C moves from point a to point b along a straight line, a total distance d=0.5m. The electric field is uniform along this line, in the direction from a to b, with magnitude E=200N/C. Determine the force on q, the work done on it by the electric field, and the potential difference V_a-V_b.

Solution

The force is in the same direction as the electric field since the charge is positive; the magnitude of the force is given by

$$F = qE = 3\times10^{-9} \times 200 = 600\times10^{-9}\text{N}$$

The work done by this force is

$$W = Fd = 600\times10^{-9} \times 0.5 = 300\times10^{-9}\text{J}$$

The potential difference is the work per unit charge, which is

$$V_a - V_b = W/q = 100\text{V}$$

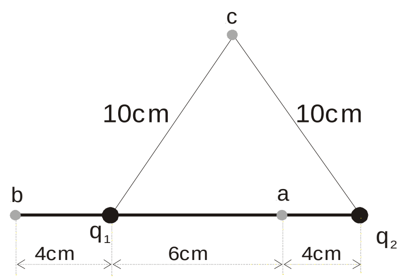
Or

$$V_a - V_b = Ed = 200 \times 0.5 = 100\text{V}$$

Example 3

Point charge of +12×10[-9]C and -12×10[-9]C are placed 10cm part as shown in the figure. Compute the potential at point *a*, *b*, and *c*.

Compute the potential energy of a point charge +4×10[-9]C if it placed at points *a*, *b*, and *c*.



Solution

We need to use the following equation at each point to calculate the potential,

$$V = \sum_n V_n = \frac{1}{4\pi\varepsilon_o}\sum \frac{q_i}{r_i}$$

<u>At point *a*</u>

$$V_a = 9\times10^9\left(\frac{12\times10^{-9}}{0.06} + \frac{-12\times10^{-9}}{0.04}\right) = -900V$$

<u>At point *b*</u>

$$V_b = 9\times10^9\left(\frac{12\times10^{-9}}{0.04} + \frac{-12\times10^{-9}}{0.14}\right) = -1930V$$

<u>At point *c*</u>

$$V_c = 9\times10^9\left(\frac{12\times10^{-9}}{0.1} + \frac{-12\times10^{-9}}{0.14}\right) = 0V$$

We need to use the following equation at each point to calculate the potential energy,

At point *a*

$$U_a = qV_a = 4\times10^{-9}\times(-900) = -36\times10^{-7}J$$

At point *b*

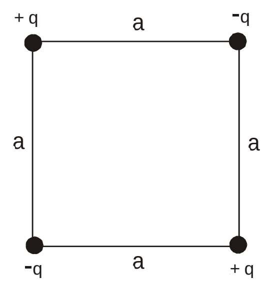
$$U_b = qV_b = 4\times10^{-9}\times1930 = +77\times10^{-7}J$$

At point *c*

$$U_c = qV_c = 4\times10^{-9}\times0 = 0$$

Example 4

Derive an expression for the work required to put the four charges together as indicated in the figure.



Solution

The work required to put these charges together is equal to the total electric potential energy.

$$U = U_{12} + U_{13} + U_{14} + U_{23} + U_{24} + U_{34}$$

$$U = \frac{1}{4\pi\varepsilon_o}\left[\frac{-q^2}{a} + \frac{q^2}{\sqrt{2}a} - \frac{q^2}{a} - \frac{q^2}{a} + \frac{q^2}{\sqrt{2}a} - \frac{q^2}{a}\right]$$

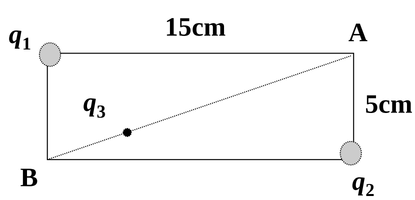
$$U = \frac{1}{4\pi\varepsilon_o}\left[\frac{-4q^2}{a} + \frac{2q^2}{\sqrt{2}a}\right]$$

$$U = \frac{1}{4\pi\varepsilon_o}\left[\frac{-\sqrt{2}4q^2 + 2q^2}{\sqrt{2}a}\right] = \frac{-0.2q^2}{\varepsilon_o a}$$

The minus sign indicates that there is attractive force between the charges

Example 5

In the rectangle shown in the figure, q_1 = -5x10^{-6}C and q_2 = 2x10^{-6}C calculate the work required to move a charge q_3 = 3x10^{-6}C from *B* to *A* along the diagonal of the rectangle.



Solution

from the equation $V_B - V_A = W_{AB} / q_o$

$$V_A = V_1 + V_2 \quad \& \quad V_B = V_1 + V_2$$

$$V_A = \frac{q}{4\pi\varepsilon_o}\left[\frac{-5\times10^{-6}}{0.15}+\frac{2\times10^{-6}}{0.05}\right] = 6\times10^4 V$$

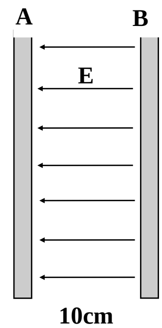
$$V_B = \frac{q}{4\pi\varepsilon_o}\left[\frac{-5\times10^{-6}}{0.05}+\frac{2\times10^{-6}}{0.15}\right] = -7.8\times10^4 V$$

$$W_{BA} = (V_A - V_B)\, q_3$$

$$=(6\times10^4 + 7.8\times10^4)\, 3\times10^{-6} = 0.414 \text{ Joule}$$

Example 6

Two large parallel conducting plates are 10 cm a part and carry equal but opposite charges on their facing surfaces as shown in the figure. An electron placed midway between the two plates experiences a force of 1.6 × 10^{-15} N.
What is the potential difference between the plates?



Solution

$$V_B - V_A = Ed$$

يمكن حساب المجال الكهربي عن طريق القوى الكهربية المؤثرة على الإلكترون

$$F = eE \Rightarrow E = F/e$$

$$V_B - V_A = 10000 \times 0.1 = 1000 \text{ volt}$$