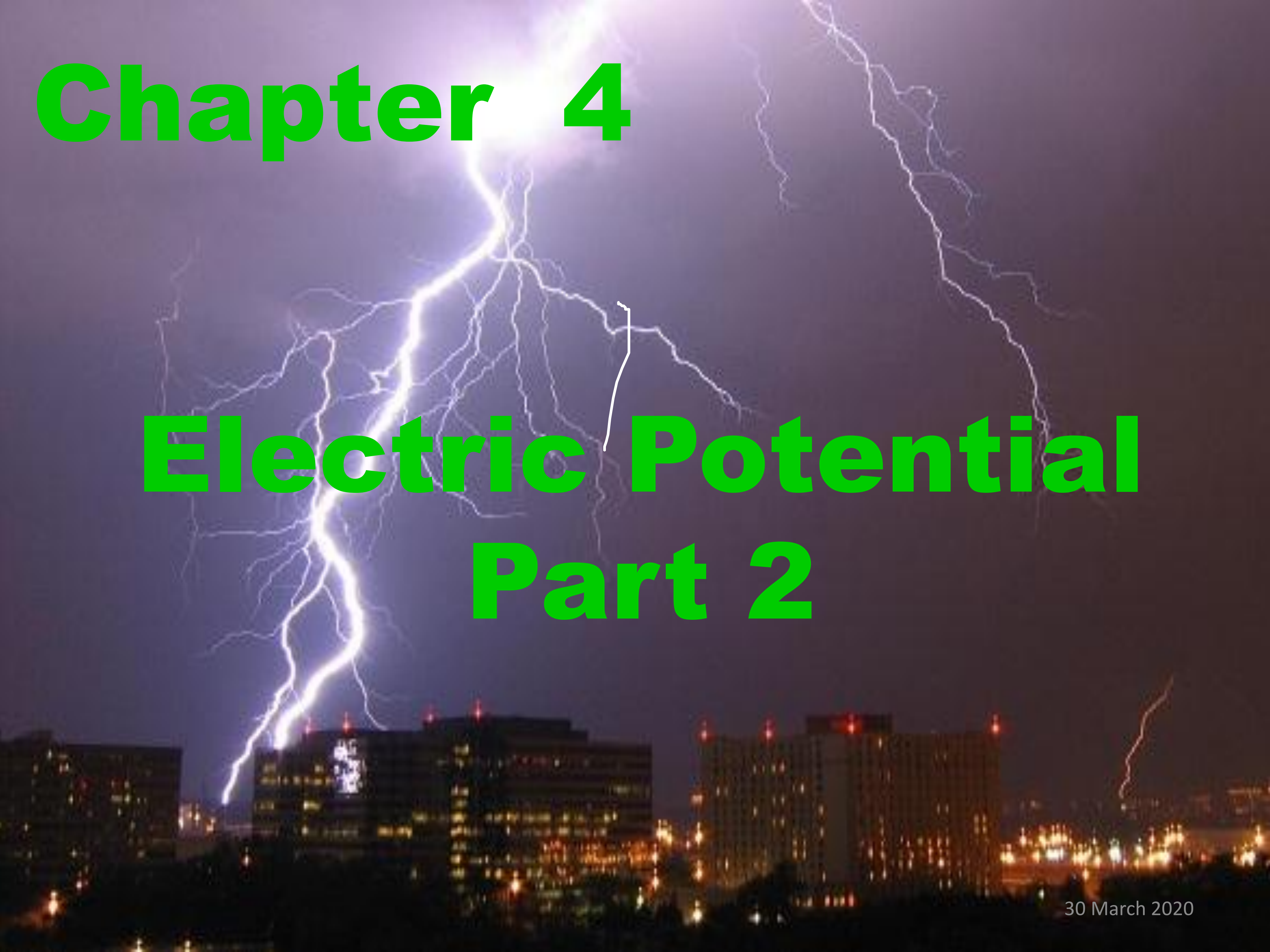


Chapter 4

Electric Potential
Part 2

30 March 2020

Intended Learning Outcomes of the lecture (ILOs):

بعد الانتهاء من الدرس تكون قادر على

When you have completed this section, the students will be able to:

حساب الجهد الكهربى الناتج من شحنة نقطية والعزم الكهربى

- Identify the Electric Potential Differences due to a **Point Charge** and **Electric Dipole**
- Understanding the concepts of Electric potential energy

  فهم مفهوم طاقة الجهد الكهربى
- Demonstrate how can determine the Electric field from potential difference شرح كيفية حساب المجال الكهربى من الجهد الكهربى
- Apply the principle laws of Electric Potential to solve some problems

  تطبيق القوانين فى بعض المسائل

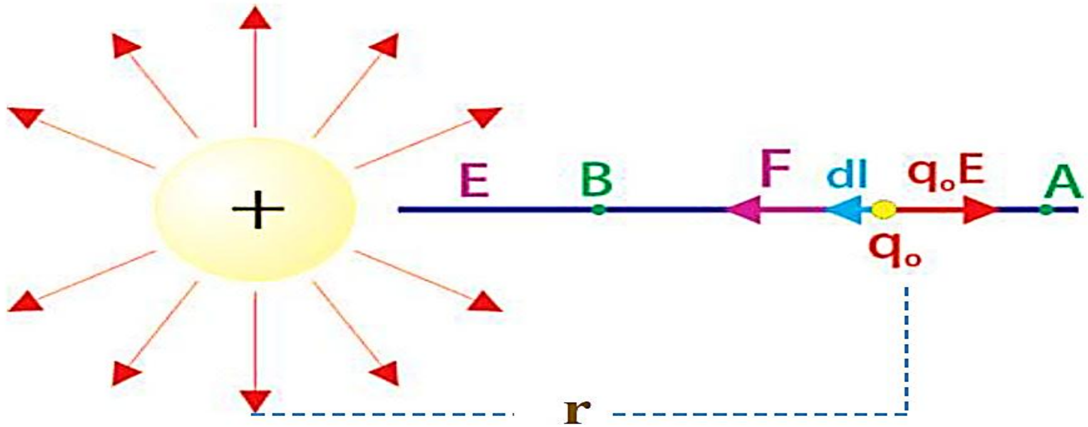
$$V = \frac{W}{q_o}$$

$$\Delta V = Ed$$ **Uniform Electric field**

$$V_f - V_i = -\int_i^f \vec{E}.\vec{ds}$$ **Non-Uniform Electric field**

POTENTIAL DUE TO A POINT CHARGE

$$\because E = \frac{1}{4\pi\varepsilon_o}.\frac{q}{r^2}$$



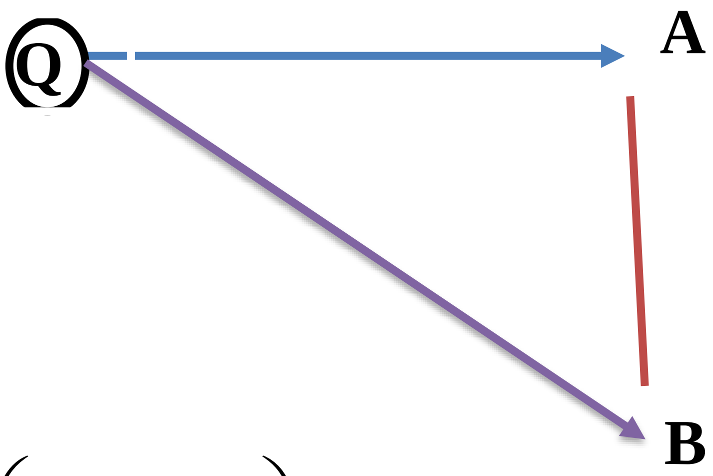
$$V = Ed$$

$$\because V = \frac{1}{4\pi\varepsilon_o}.\frac{q}{r^2}.r$$

$$\because V = \frac{1}{4\pi\varepsilon_o}.\frac{q}{r}$$

Electric potential difference is scalar

$$V_A = \frac{q}{4\pi\varepsilon_o} \cdot \left(\frac{1}{r_A}\right)$$



$$V_B = \frac{q}{4\pi\varepsilon_o} \cdot \left(\frac{1}{r_B}\right)$$

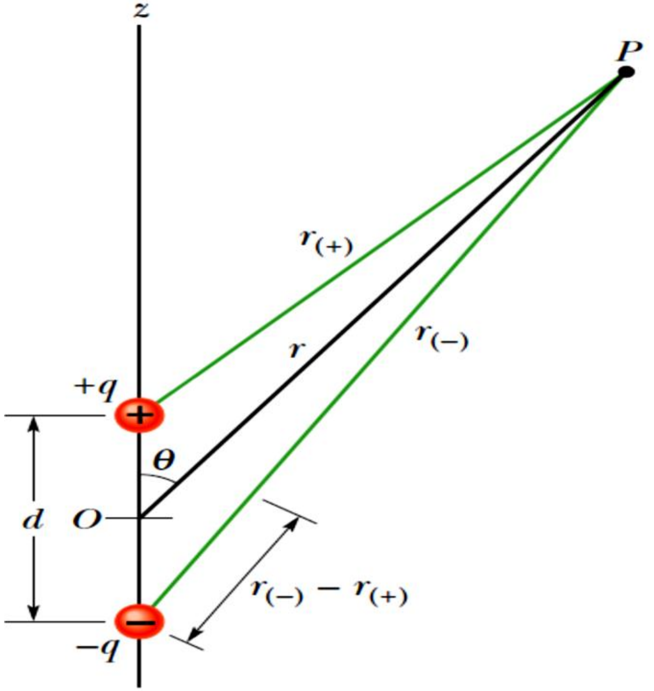
$$V_B - V_A = \frac{q}{4\pi\varepsilon_o} \cdot \left(\frac{1}{r_B} - \frac{1}{r_A}\right)$$

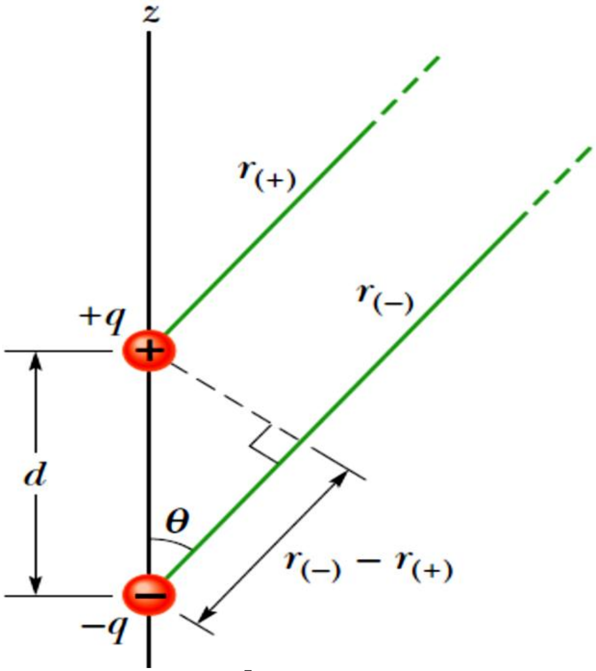
Potential Due to a Group of Point Charge

$$V_{tot} = V_1 + V_2 + V_3 + \cdots \ldots + V_n$$

$$V = \frac{1}{4\pi\varepsilon_0} \sum_1^n \frac{q_i}{r_i}$$

Potential due to an electric dipole





$$V == \frac{q}{4\pi\varepsilon_0}\left(\frac{r_{(-)}-r_{(+)}}{r_{(+)}r_{(-)}}\right) \qquad V == \frac{1}{4\pi\varepsilon_0}\left(\frac{P\cos\theta}{r^2}\right)$$ **(electric dipole)**

$V = 0$ when $\theta = 90^o$

V is the maximum positive value when $\theta = 0^o$

V is the maximum negative value when $\theta = 180^o$.

Chapter 4

ELECTRIC POTENTIAL ENERGY

Electric Potential Energy : The work required to bring them from infinity to that configuration

U = Vq₂

$$\because V = \frac{1}{4\pi\varepsilon_o}.\frac{q}{r}$$

$$\therefore U = \frac{1}{4\pi\varepsilon_o}.\frac{q_1 q_2}{r}$$

$$\therefore U = \sum \frac{1}{4\pi\varepsilon_o}.\frac{q_i q_j}{r_{ij}}$$

Chapter 4

Electric potential energy is scalar

U :- ***positive (+) this means that the exchange forces of system will be repulsive***

U :- ***Negative (-) this means that the exchange forces of system will be attractive***

ELECTRIC FIELD FROM POTENTIAL DIFFERENCE

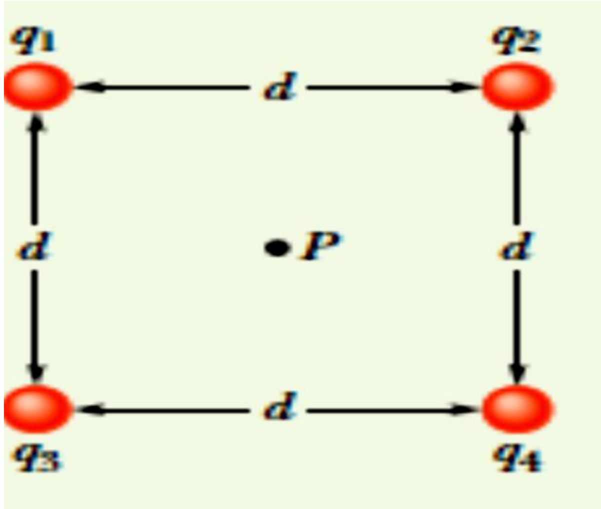
Now we determine the electric field from the electric potential by the following relation.

$$E = \frac{dV}{dr}$$

EXAMPLES

Example.1

What is the electric potential at point *P*, located at the center of the square of point charges shown in Figure? The distance *d* is 1.3 m, and the charges are.



q_1 = +12 nC , q_2 = +31 nC, q_3 = -24 nC, q_4 = +17 nC

Solution

$$V = \sum_{i=1}^{4} V_i = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{r} + \frac{q_2}{r} + \frac{q_3}{r} + \frac{q_4}{r}\right)$$

The distance ***r*** is **d/√2** , which is 0.919 m, and the sum of the charges is

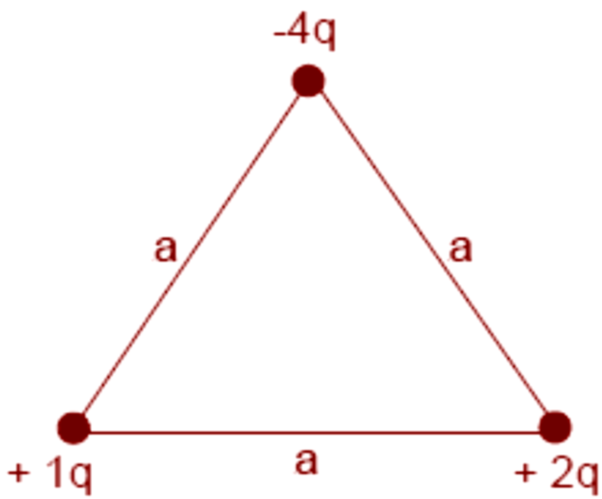
$$q_{net} = (q_1 + q_2 + q_3 + q_4) = (12 - 24 + 31 + 17) \times 10^{-9} = 36 \times 10^{-9} C$$

Thus,

$$V = \frac{1}{4\pi\varepsilon_0}\,\frac{36\times10^{-9}}{0.919} = 350\ V$$

Example.2

Three charges are held fixed as shown in the figure. What is the potential energy? Assume that q=1×10^{-7} C and a = 10cm



Solution

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

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

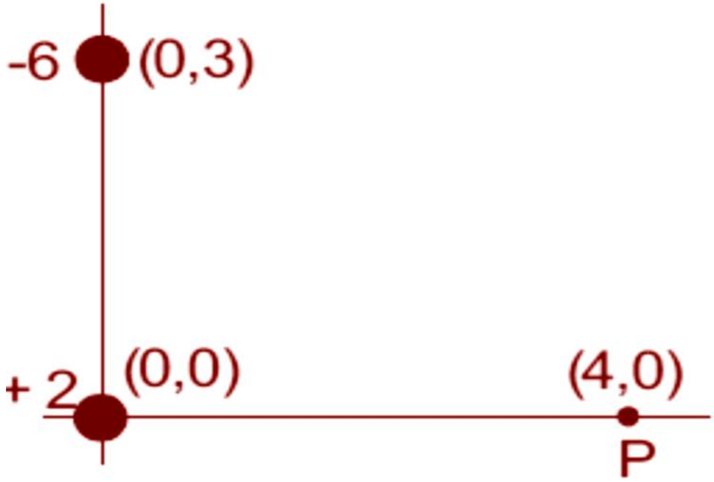
$$U = \frac{-10}{4\pi\varepsilon_o}.\left[\frac{q^2}{a}\right]$$

$$U = -\frac{9\times10^9(10)(1\times10^{-7})^2}{0.1} = -9\times10^{-3}J$$

Example.3

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

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



Solution

$$V_p = V_1 + V_2 = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{r_1} + \frac{q_2}{r_2}\right)$$

$$V = 9 \times 10^9 \left(\frac{2\times10^{-6}}{4} + \frac{6\times10^{-6}}{5}\right) = -6.3\times10^3 \text{ Vote}$$

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

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

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

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

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

$$U=\frac{1}{4\pi\varepsilon_o}\cdot\left[\frac{(2\times10^{-6})(-6\times10^{-6})}{3}+\frac{(2\times10^{-6})(3\times10^{-6})}{4}+\frac{(-6\times10^{-6})(3\times10^{-6})}{5}\right]$$

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

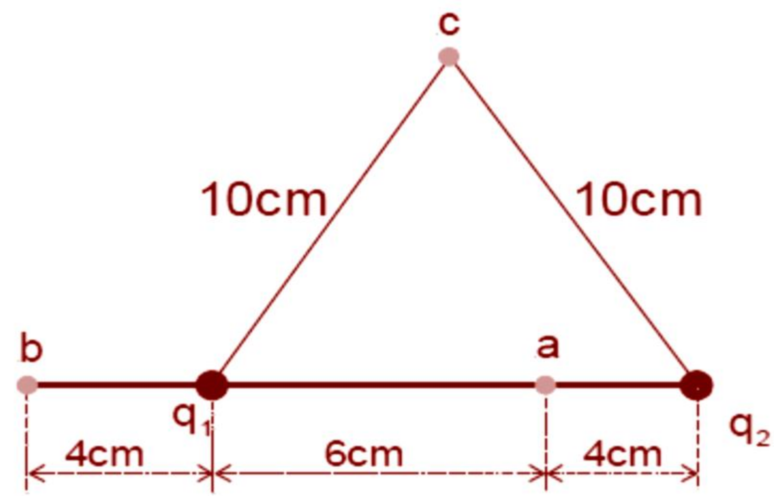
Example 4

A particle having a charge $q=3\times10^{-9}$ 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 =200 N/C. **Determine the force on q**, **the work done on it by the electric field**, and **the potential difference V_a-V_b**.

Solution Pag. 65 in book

Example.5

Point charge of $+12\times10^{-9}$C and -12×10^{-9}C are placed 10cm part as shown in figure. Compute the potential at point *a*, *b*, and *c*. Compute the potential energy of a point charge $+4\times10^{-9}$C if it placed at points *a*, *b*, and



Solution

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

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

At point *a*

$$\therefore V_a = 9\times10^9\left[\frac{12\times10^{-9}}{0.06}+\frac{-12\times10^{-9}}{0.04}\right] = -900Volt$$

At point *b*

$$\therefore V_b = 9\times10^{9}\left[\frac{12\times10^{-9}}{0.04}+\frac{-12\times10^{-9}}{0.14}\right] = -1930\,Volt$$

At point *c*

$$\therefore V_b = 9\times10^{9}\left[\frac{12\times10^{-9}}{0.1}+\frac{-12\times10^{-9}}{0.14}\right] = 0\,Volt$$

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

U= qV

At point *a*

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

At point *b*

$$U_b = qV_b = 4\times10^{-9}\times (1930) = +77\times10^{-7}\ J$$

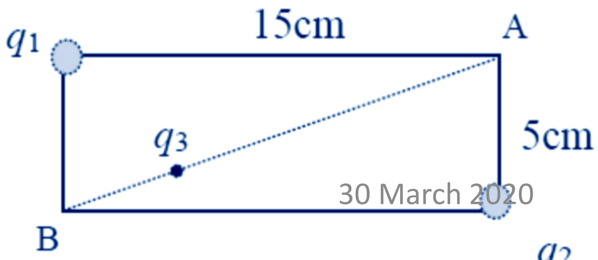
At point *c*

$$U_c = qV_c = 4\times10^{-9}\times (0) = 0\ J$$

Example 6

In the rectangle shown in 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 **Pag. 66 in book**



30 March 2020