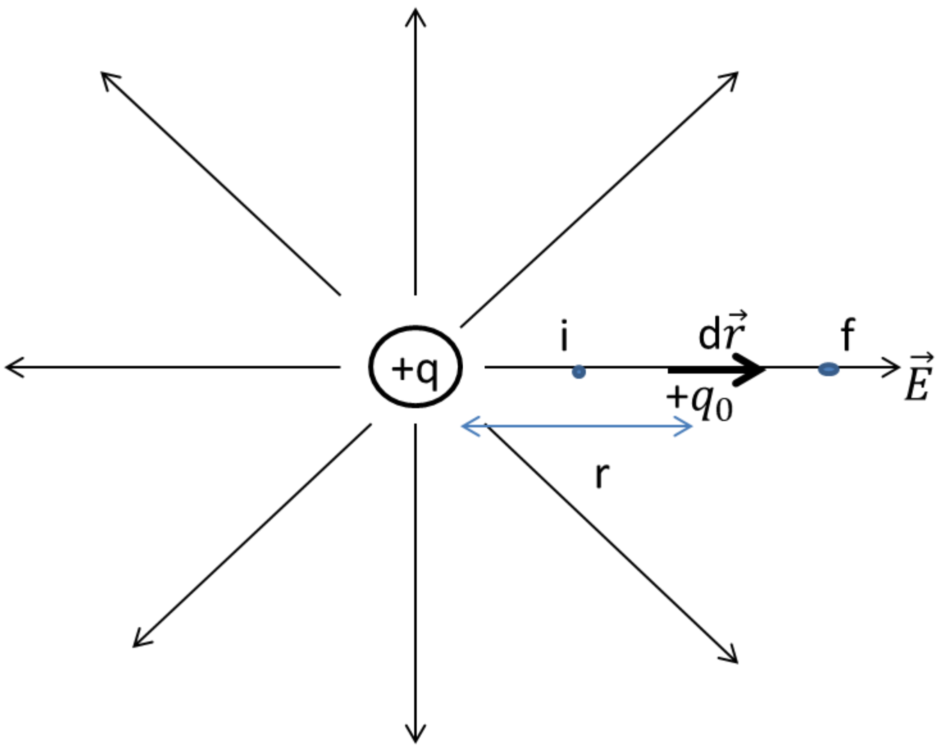
LESSON 4

BOOK CHAPTER 24

ELECTRIC POTENTIAL

Potential Due to a Point Charge:



We have $V_f - V_i = -\int_i^f \vec{E}.d\vec{s}$ …………… (iv)

$$V_f - V_i = -\int_i^f \vec{E}.d\vec{r} \qquad [\text{here } d\vec{s} = d\vec{r}]$$

$$V_f - V_i = -\int_i^f E\, cos0^0 dr$$

$$V_f - V_i = -\int_i^f E dr$$

$$V_f - V_i = -\frac{q}{4\pi\epsilon_0}\int_i^f \frac{1}{r^2} dr$$

$$V_f - V_i = -\frac{q}{4\pi\epsilon_0}\left(-\left|\frac{1}{r}\right|_{r=r_i}^{r=r_f}\right)$$

$$V_f - V_i = \frac{q}{4\pi\varepsilon_0}\left|\frac{1}{r_f} - \frac{1}{r_i}\right|$$

If r_f goes to infinity (∞), then V_f= 0 and $\frac{1}{r_f} = 0$

Hence,

$$0 - V_i = \frac{q}{4\pi\epsilon_0}\left|0 - \frac{1}{r_i}\right|$$

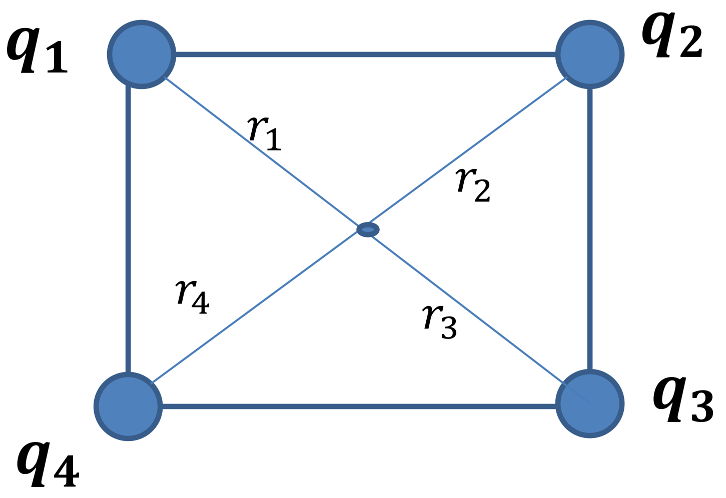
$$V_i = \frac{q}{4\pi\epsilon_0}\left|\frac{1}{r_i}\right|$$

Finally we get, $$\boxed{V = \frac{1}{4\pi\epsilon_0}\frac{q}{r}}$$

Potential Due to a Group of Point Charges:

General Formula:

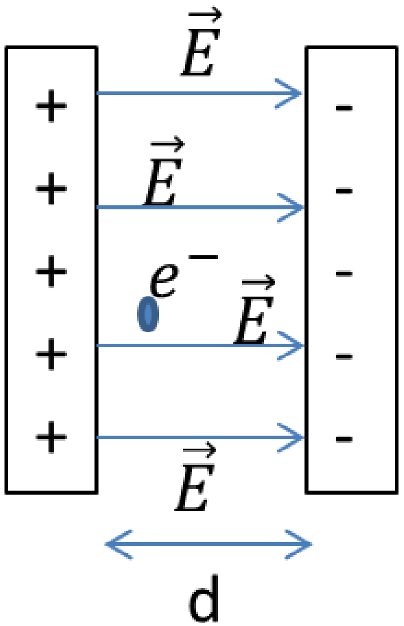
$$V = \sum_{i=1}^{n} V_i = \frac{1}{4\pi\epsilon_0} \sum_{i=1}^{n} \frac{q_i}{r_i}$$



For an example: $$V = \sum_{i=1}^{4} V_i = \frac{1}{4\pi\epsilon_0} \left[\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3} + \frac{q_4}{r_4} \right]$$

Problem: 4 (Book chapter 24)

Two large, parallel, conducting plates are 12 cm apart and have charges of equal magnitude and opposite sign on their facing surfaces. An electric force of $3.9 \times 10^{-15}\, N$ acts on an electron placed anywhere between the two plates. (Neglect fringing.) (a) Find the electric field at the position of the electron. (b) What is the potential difference between the plates?



Answer:

Given

d= 12 cm = 0.12 m

$$|F| = 3.9 \times 10^{-15} N$$

$$|e^-| = |q| = 1.6 \times 10^{-19} \mathrm{C} \qquad |E| = ?$$

(a) We know $|F| = qE$

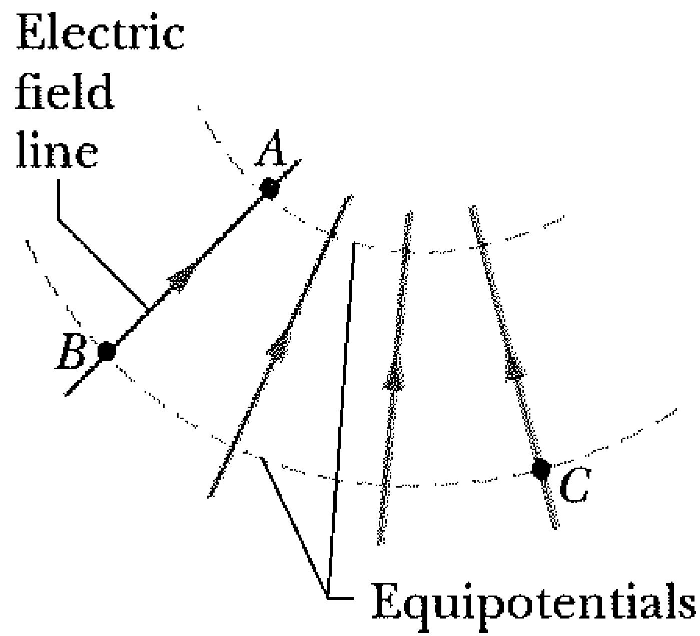
$$E = \frac{3.9 \times 10^{-15}}{1.6 \times 10^{-19}} = 2.437 \times 10^4 \frac{N}{C}$$

(b) The potential difference between the plates

$$|\Delta V| = Ed = (2.437 \times 10^4)(0.12) = 0.293 \times 10^4 \; Volt$$

Problem: 6 (Book chapter 24)

When an electron moves from *A* to *B* along an electric field line in the adjacent figure, the electric field does $3.94 \times 10^{-19}\, J$ of work on it. What are the electric potential differences
(a) $V_B - V_A$, (b) $V_C - V_A$, and (c) $V_C - V_B$?



Answer:

(a) $$V_B - V_A = \frac{-W}{q} = \frac{-3.94 \times 10^{-19}}{-1.6 \times 10^{-19}} = 2.45\, Volt$$

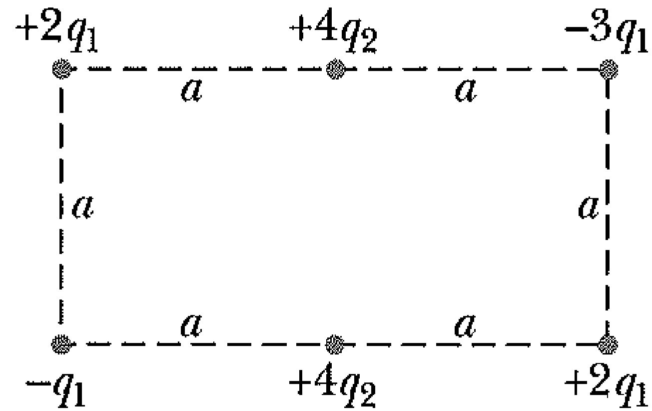
(b) $$V_c - V_A = 2.45\, Volt$$

[Because points B and C are on the same equipotential surface]

(c) $$V_c - V_B = 0\, Volt$$

Problem: 16 (Book chapter 24)

Figure shows a rectangular array of charged particles fixed in place, with distance $a = 39\ cm$ and the charges shown as integer multiples of $q_1 = 3.4\ pC$ and $q_2 = 6.0\ pC$. With $V = 0$ at infinity, what is the net electric potential at the rectangle's center? (*Hint:* Thoughtful examination of the arrangement can reduce the calculation.)

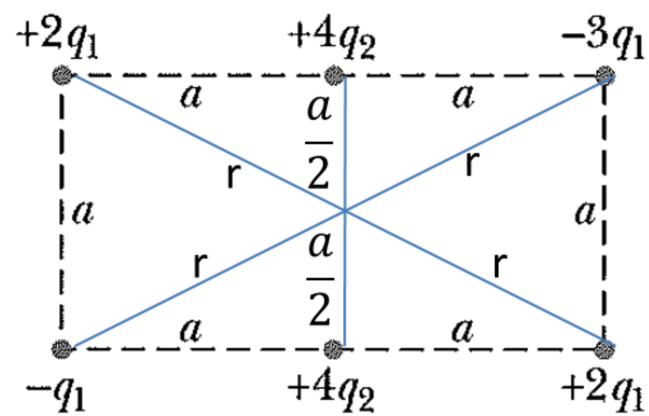


Answer:

Given $a = 39\ cm = 0.39\ m$

$q_1 = 3.40\ pC = 3.4 \times 10^{-12}\ C$

$q_2 = 6.0\ pC = 6.0 \times 10^{-12}\ C$



The net potential at the rectangle center is

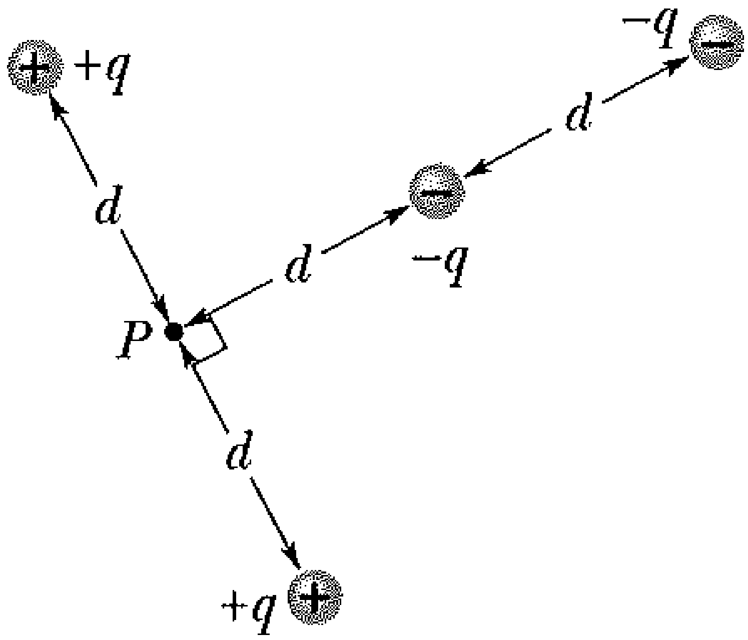
$$V = \frac{1}{4\pi\epsilon_0}\left[\frac{2q_1}{r} + \frac{-3q_1}{r} + \frac{2q_1}{r} + \frac{-q_1}{r}\right] + \frac{1}{4\pi\epsilon_0}\left[\frac{4q_2}{\frac{a}{2}} + \frac{4q_2}{\frac{a}{2}}\right]$$

$$V = 0 + \frac{1}{4\pi\epsilon_0}\left[\frac{4q_2}{0.195} + \frac{4q_2}{0.195}\right]$$

$$V = \frac{1}{4\pi\epsilon_0}\left[\frac{8q_2}{0.195}\right] = \frac{9 \times 10^9 \times 8 \times 6 \times 10^{-12}}{0.195}$$

V =2.215 Volt

Problem: 17 (Book chapter 24)



In the adjacent Figure, what is the net electric potential at point *P* due to the four particles if $V = 0$ at infinity, $q = 5\ fC$, and $d = 4\ cm$?

Answer:

Given

$q = 5\ fC = 5 \times 10^{-15}\ C$ and $d = 4\ cm = 0.04\ m$

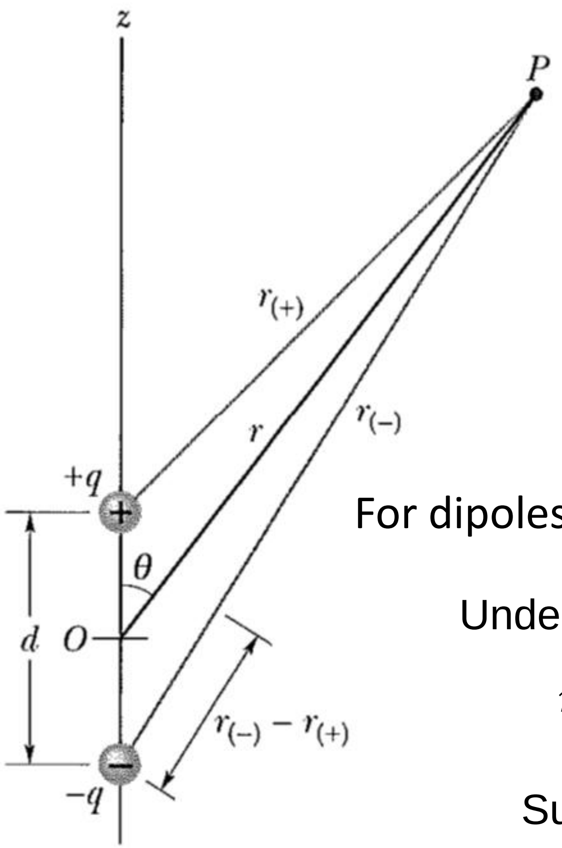
The net electric potential at the point P is

$$V = \frac{1}{4\pi\epsilon_0}\left[\frac{q}{d} + \frac{q}{d} + \frac{-q}{d} + \frac{-q}{2d}\right]$$

$$V = \frac{9 \times 10^9 \times q}{d}\left[1 + 1 - 1 - \frac{1}{2}\right]$$

$$V = \frac{9 \times 10^9 \times 5 \times 10^{-15}}{0.04 \times 2} = 562.5 \times 10^{-6}\ Volt$$

Potential Due to an Electric Dipole:



The net potential at *P* is given by

$$V = \sum_{i=1}^{2} V_i = V_{(+)} + V_{(-)} = \frac{1}{4\pi\varepsilon_0}\left[\frac{q}{r_{(+)}} + \frac{-q}{r_{(-)}}\right]$$

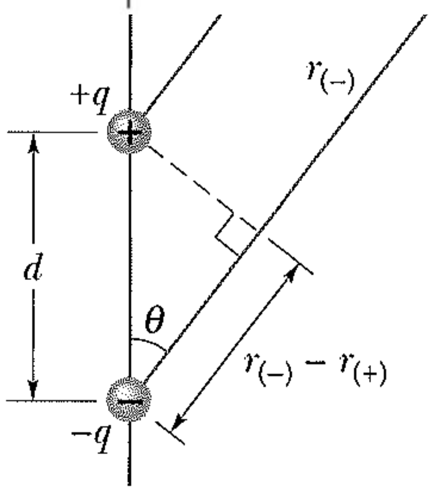
$$V = \frac{q}{4\pi\varepsilon_0}\left(\frac{r_{(-)} - r_{(+)}}{r_{(-)}r_{(+)}}\right)$$

For dipoles, usually, $r \gg d$, where d is the distance between the charges.

Under the above condition, from the figure we can write

$$r_{(-)} - r_{(+)} = d\cos\theta \quad and \quad r_{(-)}r_{(+)} \approx r^2$$

Substituting these values in the above equation, we get



$$V = \frac{q}{4\pi\varepsilon_0}\left(\frac{d\cos\theta}{r^2}\right)$$ where, θ is measured from the dipole axis as shown in the figure.

$$\boldsymbol{V = \frac{1}{4\pi\varepsilon_0}\left(\frac{p\cos\theta}{r^2}\right)}$$ where, $p\ (= qd)$ *is the magnitude of* electric dipole moment $\vec{p}$.

The vector $\vec{p}$ is directed along the dipole axis, from the negative to the positive charge.

THANK YOU