24.3 Electric Potential and Electric Energy Due to a Point Charge:

Remember!

1. Electric Potential (V)

- **Definition**: The amount of **electric potential energy per unit charge** at a point in an electric field.
- **Formula**: V= $\frac{U}{q}$; where V is the electric potential (volts), U is the electric potential energy (joules), and q is the charge (coulombs).
- **Key Idea**: It describes how much energy a unit charge would have at a certain point due to the electric field.
- **Unit**: Volts (V) = Joules per Coulomb (J/C).

---

2. Electric Potential Energy (U)

- **Definition**: The **energy stored** in a system of charges due to their positions in an electric field.
- **Formula**: $U = qV$; where U is the potential energy, q is the charge, and V is the electric potential at that point.
- **Key Idea**: It depends on both the charge **q** and the electric potential **V**. It tells us how much work is needed to move a charge within an electric field.
- **Units**: Joules (J).

---

3. Electric Potential Difference (ΔV) (Voltage)

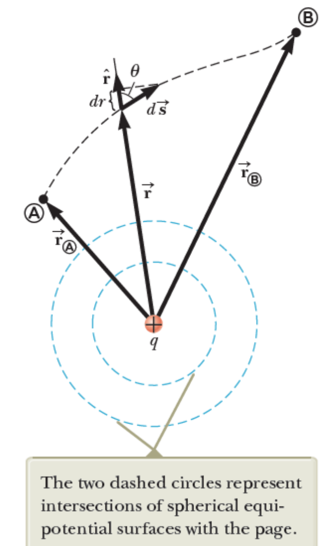
- **Definition**: The difference in electric potential between two points in an electric field, representing the work required to move a unit charge **from one point to another**.
- **Formula**: $\Delta V = V_B - V_A = \frac{W}{q}$; where W is the work done to move the charge from point A to point B.
- **Key Idea**: This is what drives current in a circuit—it's often referred to as "voltage."
- **Units**: Volts (V).

- **The potential difference is also given as:**

$$V_{AB} = V_B - V_A = -\int_A^B E ds \cos\theta = -K\int_{r_A}^{r_B} \frac{q}{r^2} dr \cos\theta = K\frac{q}{r}\Big|_{r_A}^{r_B} = Kq\Big[\frac{1}{r_B} - \frac{1}{r_A}\Big]$$

- The electric potential created by a point charge at any distance r is given by:

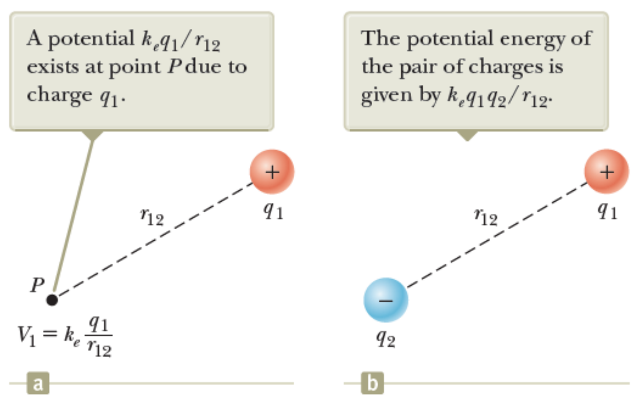
$$V = K\frac{q}{r}$$

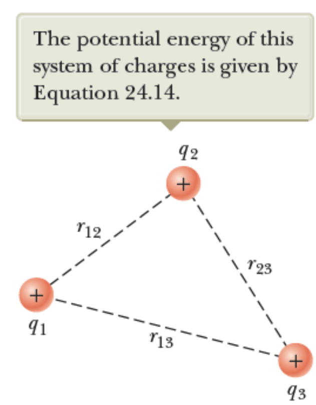


This can be derived if we assume that we choose the reference of electric potential for a point charge to be $V_A = 0$ at $r_A = \infty$.

- For a group of point charges, we can write the potential energy as follows:

$$V = k\frac{q_1}{r_1} + k\frac{q_2}{r_2} + \ldots = K\sum\frac{q_n}{r_n}$$



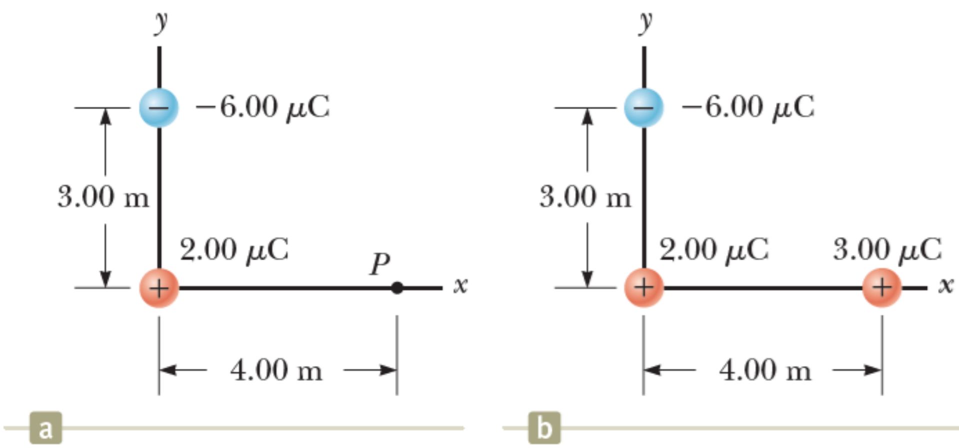


Potential energy is also given by:

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

Or, $$U = K\left[\frac{q_1 q_2}{r_{12}} + \frac{q_1 q_3}{r_{13}} + \frac{q_2 q_3}{r_{23}} + \cdots\right]$$

Example-1



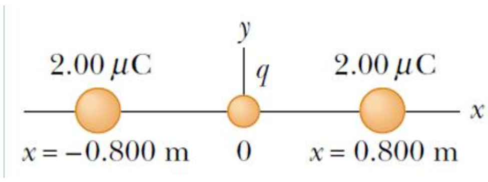
As shown in the Figure, a charge $q_1 = 2.00\ \mu C$ is located at the origin and a charge $q_2 = -6.00\ \mu C$ is located at (0,3.00) m.

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

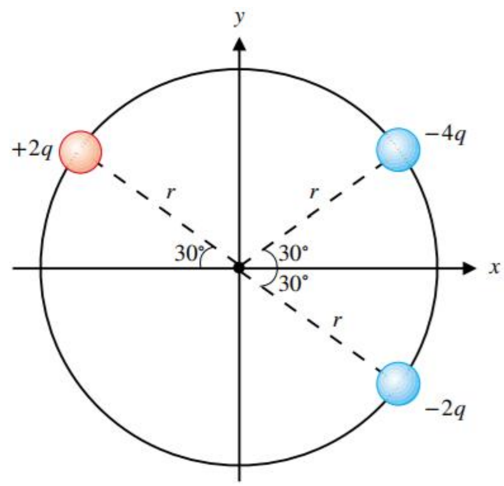
(B) Find the change in potential energy of the system of two charges plus a third charge $q_3 = 3.00\ \mu C$ as the latter charge moves from infinity to point *P.*

Exampl-2

Given two 2.00 μC charges, as shown in the figure, and a positive test charge $q = 1.28 \times 10^{-18}$ C at the origin, (a) what is the net force exerted by the two 2.00 μC charges on the test charge *q*? (b) What is the electric field at the origin due to the two 2.00 μC charges? (c) What is the electric potential at the origin due to the two 2.00 μC charges?



Example-3



Three charges are located on the circumference of a circle with a radius r=10 cm as shown in the figure. Assuming, q= 6 nC, the total electric potential due to these charges at the center of the circle in (kV) unit is:

Example-4:

An electron is released in a region with a varying electric potential. The electron moves towards the region with:

A. higher electric potential and it loses potential energy.

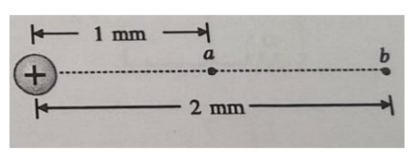
B. higher electric potential and it gains potential energy.

C. lower electric potential and it loses potential energy.

D. lower electric potential and it gains potential energy.

Example 5: The figure shows two points near a positive point charge. The potential difference, V_a-V_b equals:

A. $V_a/4$ B. $V_a/2$ C. $2V_a$ D. $4V_a$



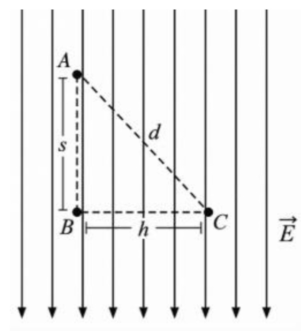
Exercise -1 :

If the magnitude of the electric field at a distance r_1 from the center of an infinite sheet of positive charge is E_1, then at a distance $r_2 = 2r_1$, the electric field E_2 equals:

A. $E_1/2$
B. E_1
C. $2E_1$
D. 4E1

Exercise -2 :

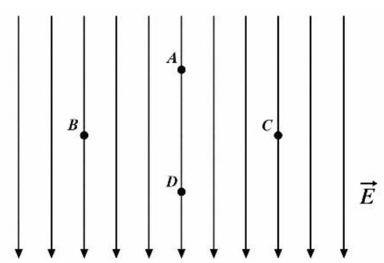
In a region of uniform electric field E, as shown in the figure, the potential difference between points A and C $(V_A - V_C)$ is:



A. Ed
B. Es
C. Ed/h
D. Es/h

Exercise -3 :

The points A, B, C, and D are located in a region of uniform electric field $\vec{E}$, as shown in the figure. The highest electric potential is at point:



A. A
B. B
C. C
D. D