Part I: Electricity

Chapter 25

Electric Potential

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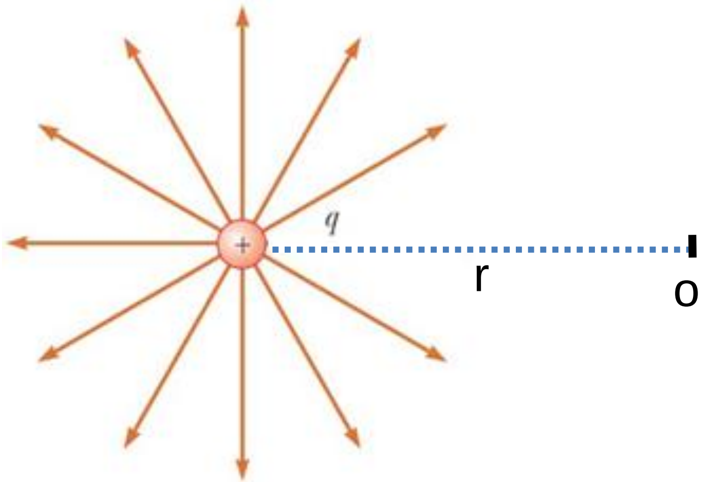
LECTURE OUTLINE

- **25.1** Electric Potential and Potential Difference
- **25.3** Electric Potential and Potential Energy Due to Point Charges
- **25.4** Obtaining the Value of the Electric Field from the Electric Potential

25.1 Electric Potential and Potential Difference

Potential due to point charge الجهد الكهربي لنقطة مشحونة



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

- Potential difference in uniform electric field.
- Electric potential point charge.

Electric potential

Potential and Potential Energy

The *potential is characteristic of the field only,* independent of a charged particle that may be placed in the field. *Potential energy is characteristic of the charge-field system* due to an interaction between the field and a charged particle placed in the field.

Electric Potential and Potential Difference

$$V_{B} - V_{A} = \Delta V = -\int_{A}^{B} \vec{\mathbf{E}} \cdot d\vec{\mathbf{s}} = -\int_{A}^{B} E\,ds\,(\cos 0^\circ) = -\int_{A}^{B} E\,ds$$

$$\Delta V = -E\int_{A}^{B} ds$$

$$\Delta U = q\,\Delta V = -qEd$$

$$\Delta V = -Ed$$

$$W = q\,\Delta V$$

that the SI unit of electric field (N/C) can also be expressed in volts per meter:

$$1\ \frac{\mathrm{N}}{\mathrm{C}} = 1\ \frac{\mathrm{V}}{\mathrm{m}}$$

$$1\ \mathrm{V} \equiv 1\ \frac{\mathrm{J}}{\mathrm{C}}$$

Potential difference and electric potential

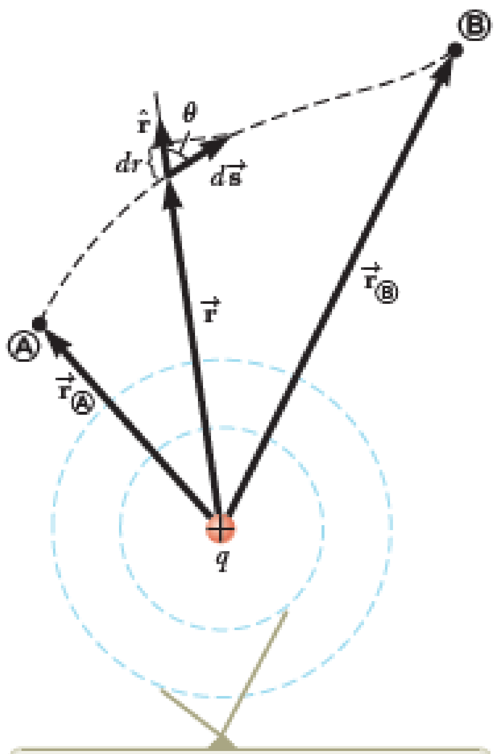
- The potential difference $\Delta V = V_B - V_A$ between two points A and B in an electric field is defined as the change in potential energy of the system when a test charge is moved between the points divided by the test charge q_o:

$$\Delta V \equiv \frac{\Delta U}{q_0} = -\int_A^B \mathbf{E} \cdot d\mathbf{s}$$

Electric Potential Energy

- Electrical potential energy is the energy contained in a configuration of charges. Like all potential energies, when it goes up the configuration is less stable; when it goes down, the configuration is more stable.
- The unit is the Joule.

25.3 Electric Potential and Potential Energy Due to Point Charges



The two dashed circles represent intersections of spherical equipotential surfaces with the page.

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

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

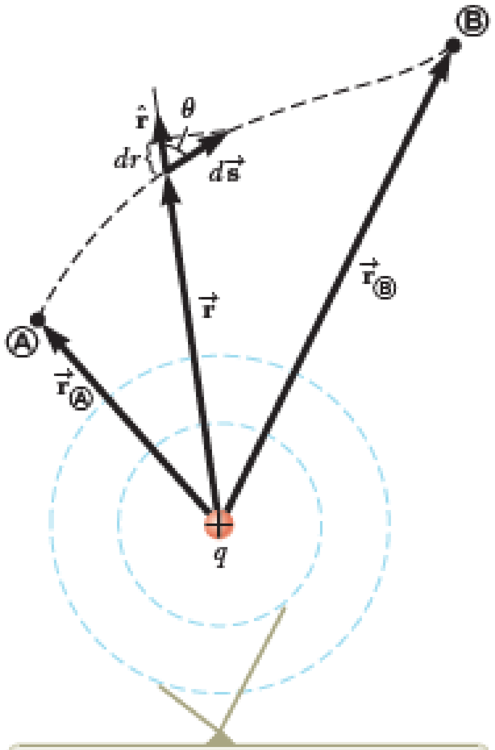
$$V_B - V_A = k_e q \left[\frac{1}{r_B} - \frac{1}{r_A}\right]$$

The electric potential is a measure of potential energy per unit charge, the SI unit of both electric potential and potential difference is joules per coulomb, which is defined as a volt (V)

For a group of point charges, we can write the total electric potential at *P* as

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

Electric Potential and Potential Energy Due to Point Charges



The two dashed circles represent intersections of spherical equipotential surfaces with the page.

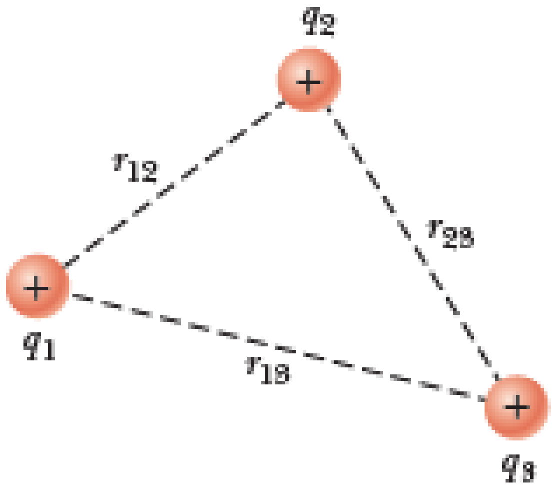
The **electric potential energy** of a pair of point charges[1] can be found as follows:

$$\Delta U = W = q_2 \Delta V \;\rightarrow\; U - 0 = q_2\left(k_e \frac{q_1}{r_{12}} - 0\right)$$

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

Electric Potential and Potential Energy Due to Point Charges

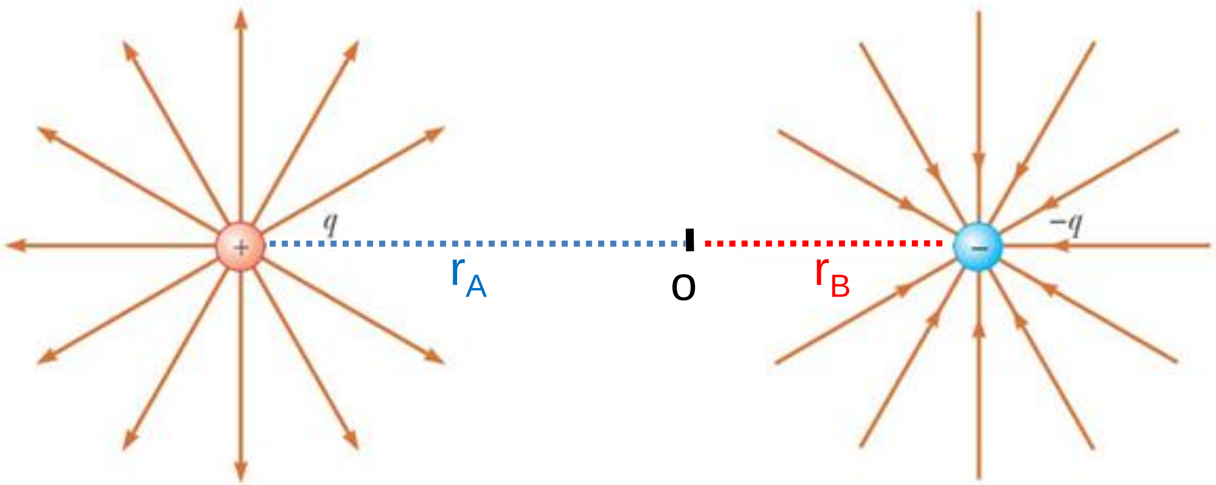
The potential energy of this system of charges is given by Equation 25.14.



the total potential energy of the system of three charges

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

The Electric Potential Due to Two Point Charges



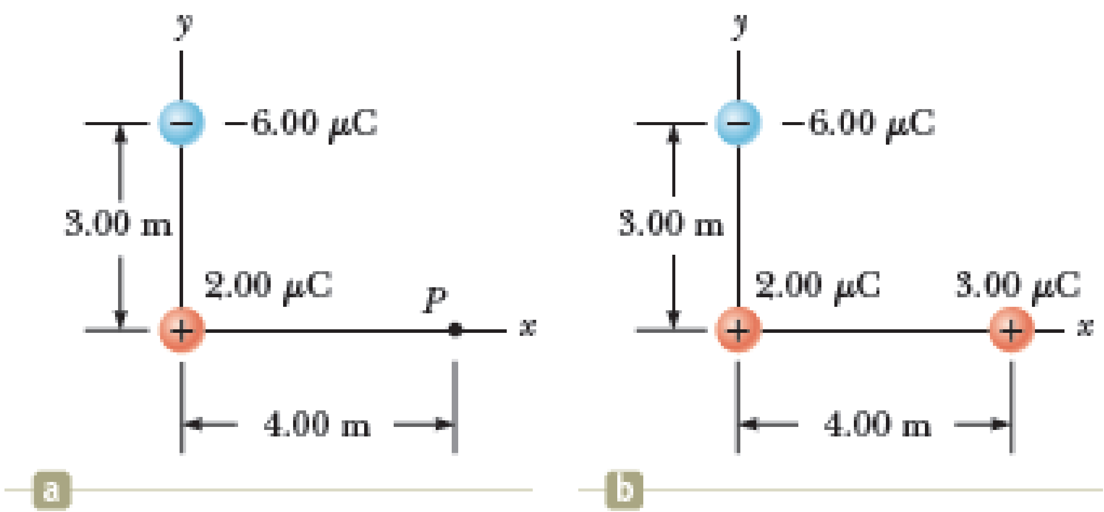
$$V = K_e\left(\frac{+q}{r_A} + \frac{-q}{r_B}\right)$$

The Electric Potential Due to Two Point Charges

As shown in Figure 25.10a, a charge q_1 5 2.00 µC is located at the origin and a charge q_2 5 26.00 µC 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 5 3.00 µC as the latter charge moves from infinity to point *P* (Fig. 25.10b).

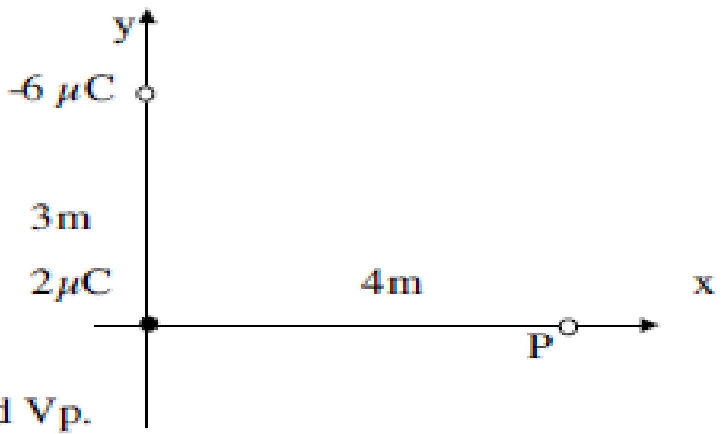


$$V_P = k_e\left(\frac{q_1}{r_1} + \frac{q_2}{r_2}\right)$$

$$U_f = q_3 V_P$$

The Electric Potential Due to Two Point Charges

<u>Example: The potential Due to Two Point Charges</u>



(a) Find Vp.

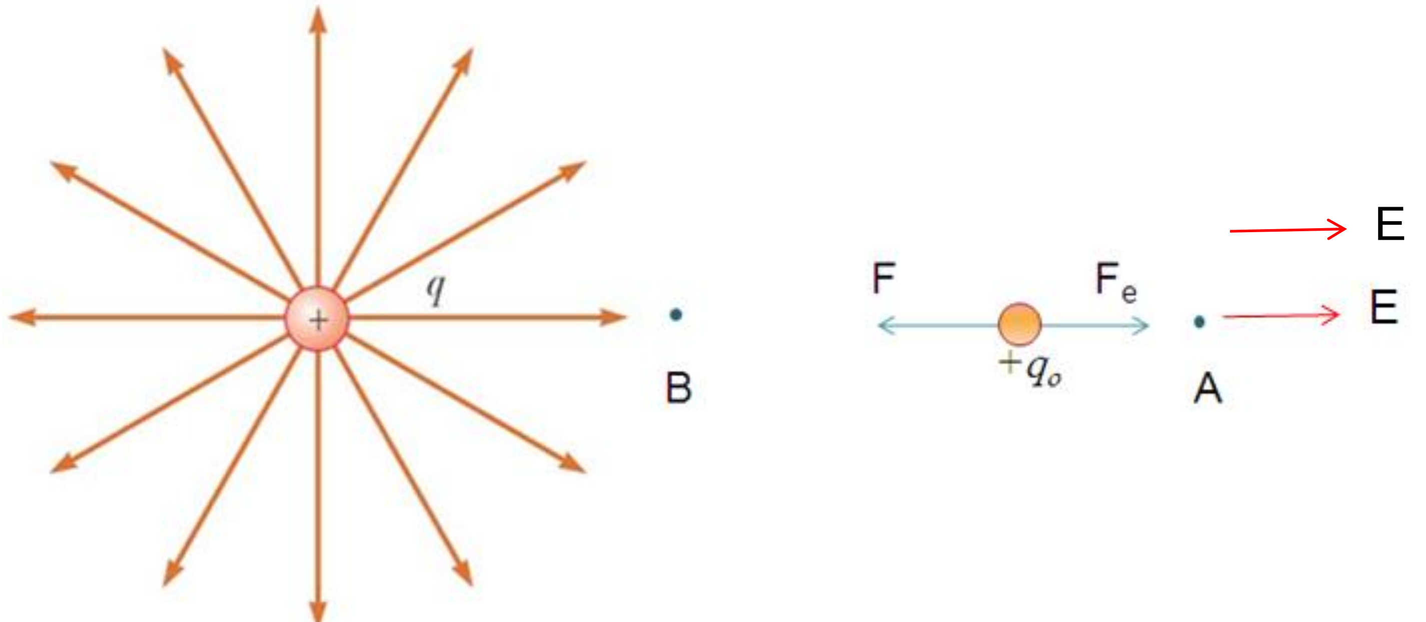
$$V_p = k_e\left(\frac{q_1}{r_1} + \frac{q_2}{r_2}\right)$$

$$V_p = 8.99\times10^9\,\frac{Nm^2}{C^2}\left(\frac{2\times10^{-6}C}{4m} - \frac{6\times10^{-6}C}{5m}\right) = -6.29\times10^3\,V$$

(b) Find the work required to bring a 3 μC charge from ∞ to P.

$$W = q_3V_p = (3\times10^{-6}\,C)(-6.29\times10^3\,V) = -18.9\times10^{-3}\,J$$

Potential difference due to point charge فرق الجهد لنقطة مشحونة



فرق الجهد بين النقطتين B, A يمثل الشغل المبذول لنقل وحدة الشحنة الموجبة q_o من A إلى B عكس اتجاه المجال الكهربي

$$V_{AB} = \frac{U_{AB}}{q_o}$$

حيث U_{AB} تمثل طاقة الوضع

25.4 Obtaining the Value of the Electric Field from the Electric Potential

If the electric field has only one component

$$E_x = - dV / dx$$

Two things about E and V:

- The electric field points in the direction of **decreasing electric potential.**
- The electric field is always **perpendicular** to the equipotential surface.

Electric Field and Electric Potential

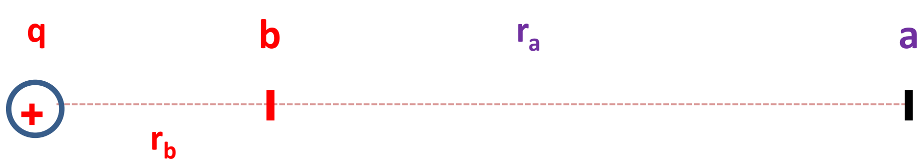
If the charge distribution creating an electric field has spherical symmetry such that the volume charge density depends only on the radial distance *r*, the electric field is radial.

$$E_r = -\frac{dV}{dr}$$

Electric Potential

(A) Calculate the electric potential at points a and b on the *x* axis.
(B) Calculate the work to remove the charge q_o from point a to b.

- ما قيمة الجهد الكهربي عند النقطتين b, a تبعدان مسافة r_a , r_b على الترتيب من الشحنة q. ثم احسب الشغل المبذول لنقل شحنة q_o قدرها $2.5\text{x}10^{-7}$ كولوم من a إلى b. حيث أن:
- $r_a = 1$ m , $r_b = 0.1$ m , $q = 1\text{x}10^{-6}$ C



Electric Potential

الحـل

$$V_a = K_e \frac{q}{r_a} = 9000\ Volt$$

$$V_b = K_e \frac{q}{r_b} = 90000\ Volt$$

$$V_{ab} = V_b - V_a = 90000 - 9000 = 81000\ \ Volt$$

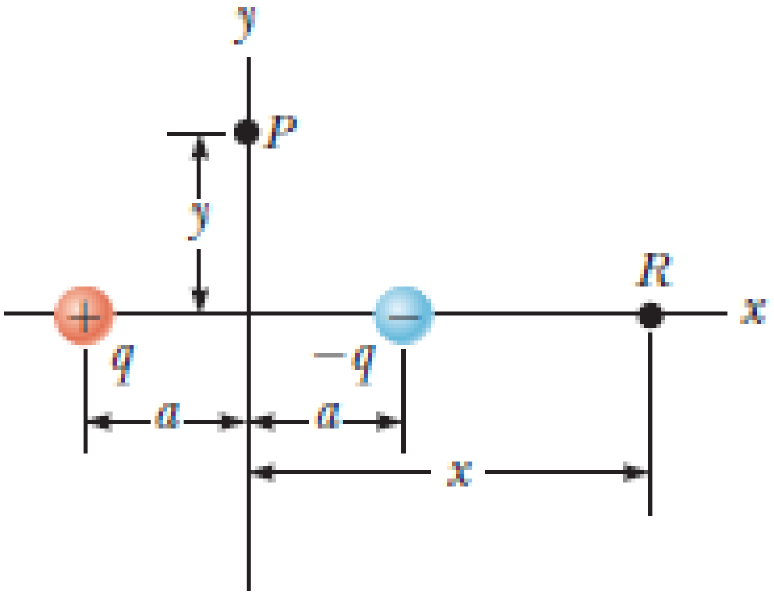
$$\mathrm{U}_{\mathrm{ab}} = q_o V_{ab} = 2.5 \times 10^{-7} \times 81000 = 0.02\ \ \ Joule$$

The Electric Potential Due to a Dipole

An electric dipole consists of two charges of equal magnitude and opposite sign separated by a distance 2*a* as shown in Figure. The dipole is along the *x* axis and is centered at the origin.

(A) Calculate the electric potential at point *P* on the *y* axis.

(B) Calculate the electric potential at point *R* on the positive *x* axis.



$$V_P = k_e \sum_i \frac{q_i}{r_i} = k_e \left(\frac{q}{\sqrt{a^2 + y^2}} + \frac{-q}{\sqrt{a^2 + y^2}} \right) = 0$$

$$V_R = k_e \sum_i \frac{q_i}{r_i} = k_e \left(\frac{-q}{x - a} + \frac{q}{x + a} \right) = -\frac{2k_e q a}{x^2 - a^2}$$

Summary الخلاصة

- المجال الكهربي

The potential difference $\Delta V = V_B - V_A$ between two points A and B in an electric field is defined as the change in potential energy of the system when a test charge is moved between the points divided by the test charge q_o:

- الجهد عند نقطة تبعد مسافة r عن الشحنة q

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

- طاقة الوضع أو الشغل المبذول لنقل شحنة q_o من A إلى B

$$U_{AB} = q_o V_{AB}$$

Thank You

ACKNOWLEDGEMENTS