King Saud University
College of Science
Physics & Astronomy Dept.

111 PHYS (GENERAL PHYSICS 2)
CHAPTER 23: Electric Fields
LECTURE NO. 4

Presented by Nouf Alkathran

23.6 Electric Field Lines

- A convenient way of visualizing electric field patterns is to draw lines, called **electric field lines** and first introduced by **Faraday**.

- ✓ $\vec{\mathbf{E}}$ is tangent to the electric field line at each point.
- ✓ The direction, indicated by an arrowhead of the line.
- ✓ The direction of the line is that of the force on a positive charge placed in the field.
- ✓ The number of lines per unit area through a surface perpendicular to the lines is proportional to the magnitude of the electric field. When lines close together **E** is strong while if they are far apart E is weak.

23.6 Electric Field Lines

The relationship between strength of E and the density of field lines:

Increase the number of electric field line (N) per unit area of a surface means increase the electric field density→→ increase the strength of E

For example:

- consider an imaginary spherical surface of radius, r, concentric with a point charge.

  $N/4\pi r^2$

E is proportional to the number of lines per unit area, we see that E varies as $1/r^2$ as the finding of

$$\vec{\mathbf{E}} = k_e \frac{q}{r^2}\hat{\mathbf{r}}$$

23.6 Electric Field Lines

Electric lines of a positive source charge:

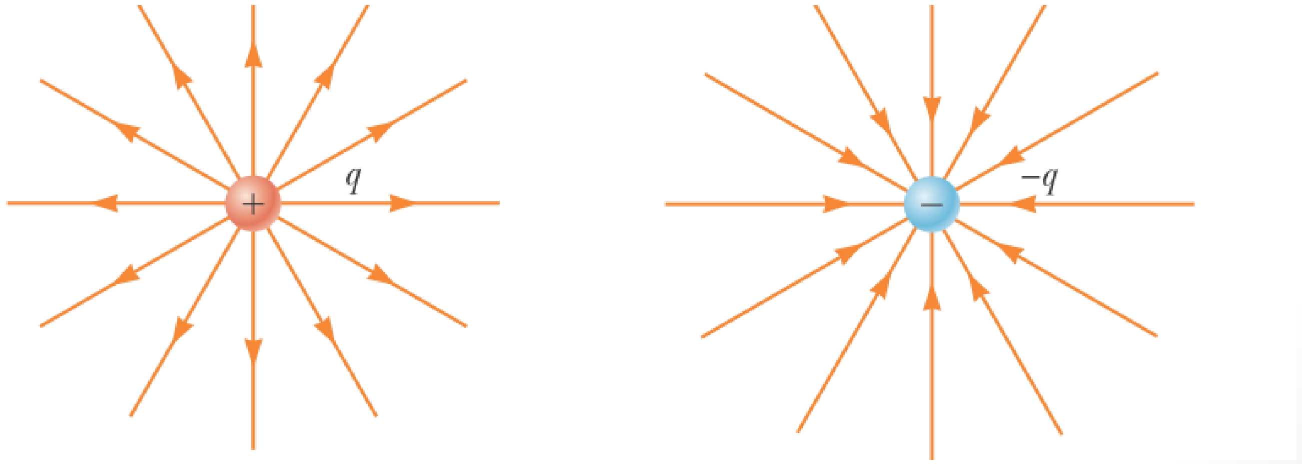
✓ directed radially away from the source charge to infinity.

Electric lines of a negative source charge:

✓directed radially toward the source charge from infinity.

Notice that:

lines become closer together as they approach the charge, indicating that the strength.



23.6 Electric Field Lines

The rules for drawing electric field lines:

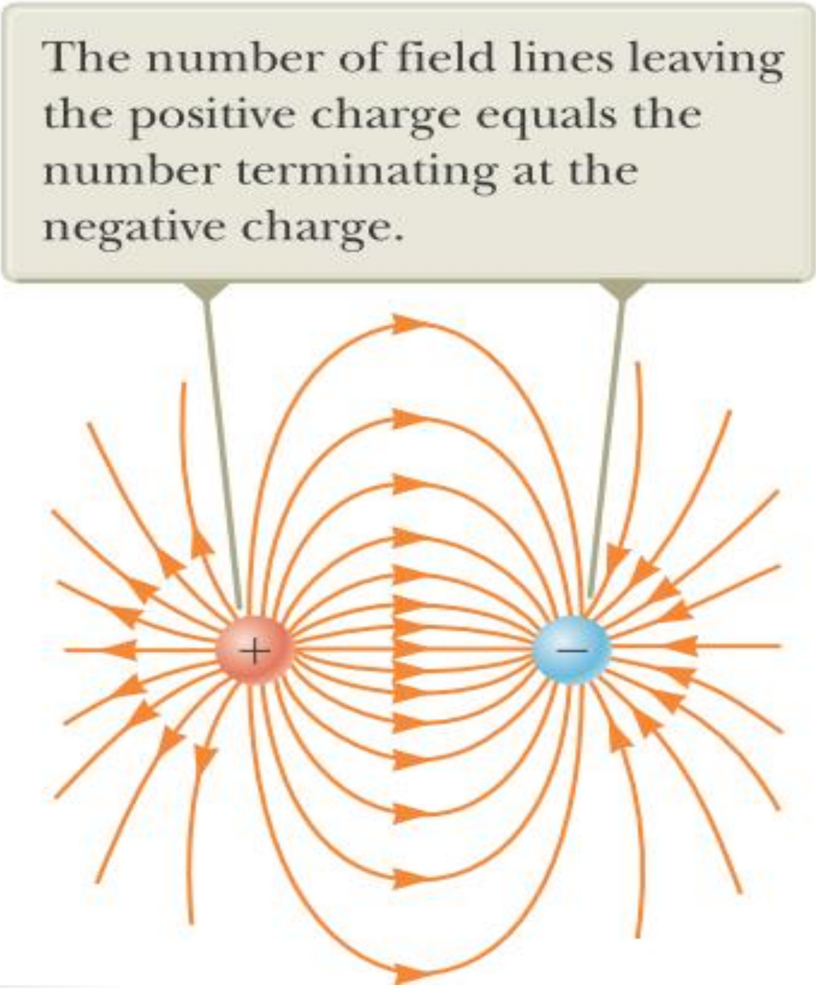
- The lines must begin on a positive charge and terminate on a negative, some lines will begin or end infinitely far away.

- The number of lines drawn is proportional to the magnitude of the charge.

- No two field lines can cross.

23.6 Electric Field Lines

Electric Field Lines of +Q, -Q: Electric Field Lines of +Q, +Q:



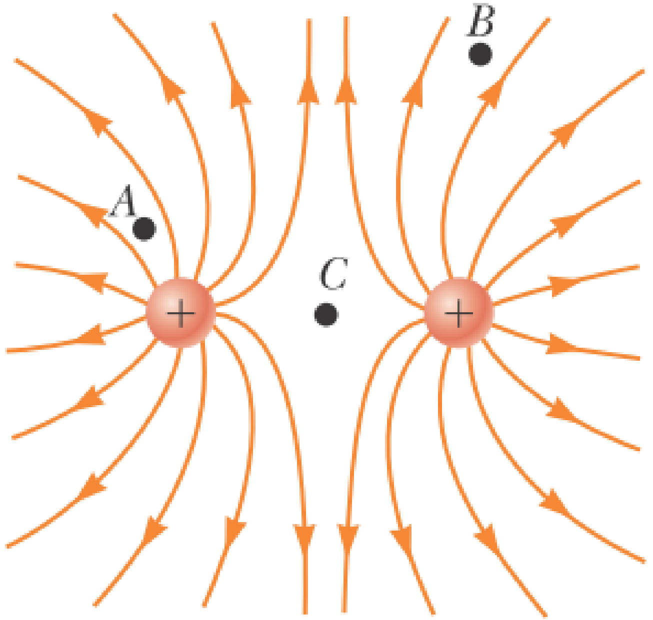


Figure 23.21 The electric field lines for two positive point charges. (The locations *A*, *B*, and *C* are discussed in Quick Quiz 23.5.)

23.6 Electric Field Lines

Electric Field Lines of +2q, -q

The number of lines leaving +2q is twice the number terminating at 2q. Hence, only half the lines that leave the positive charge reach the negative charge. The remaining half terminate on a negative charge we assume to be at infinity.

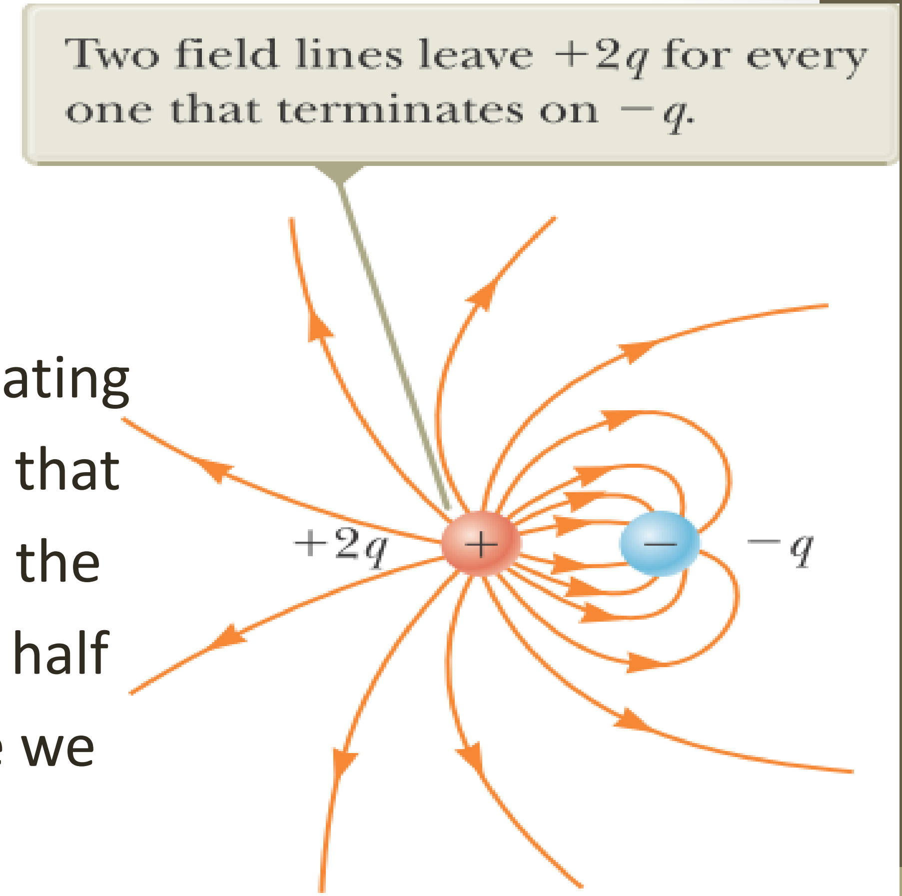


Figure 23.22 The electric field lines for a point charge $+2q$ and a second point charge $-q$.

23. 7 Motion of a Charged Particle in a Uniform Electric Field

When a particle of charge q and mass m is placed in an electric field **E**, If the only force exerted on this particle, we can write:

$$\vec{\mathbf{F}}_e = q\vec{\mathbf{E}} = m\vec{\mathbf{a}}$$

and the acceleration of the particle is:

$$\vec{\mathbf{a}} = \frac{q\vec{\mathbf{E}}}{m}$$

- If the charge of the particle is positive (+q), its **a** is in the direction of **E .**
- If the charge of the particle is negative (-q), its **a** is in the direction opposite of **E .**

23. 7 Motion of a Charged Particle in a Uniform Electric Field

If **E** is uniform and the particle is free to move, **F** on the particle is constant and we can apply the particle under constant **a** model to the motion of the particle.

Therefore, the particle in this situation is described by three analysis models:

- particle in a field
- particle under a net force
- particle under constant acceleration

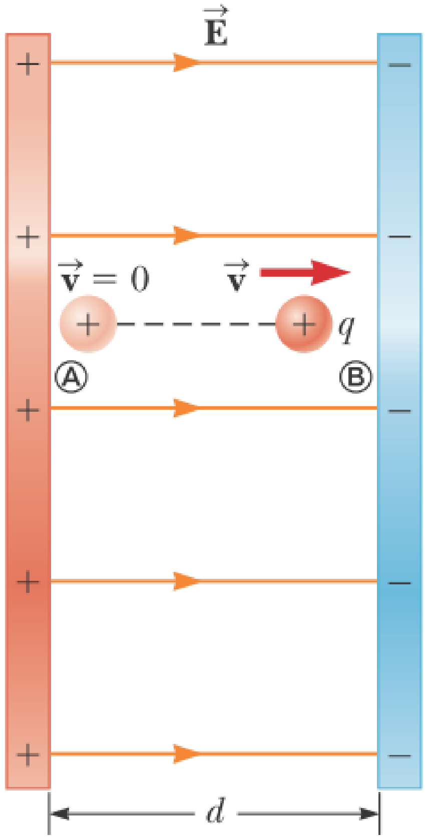
Example 23.10 An Accelerating Positive Charge: Two Models AM

A uniform electric field $\vec{\mathbf{E}}$ is directed along the x axis between parallel plates of charge separated by a distance d as shown in Figure 23.23. A positive point charge q of mass m is released from rest at a point Ⓐ next to the positive plate and accelerates to a point Ⓑ next to the negative plate.

(A) Find the speed of the particle at Ⓑ by modeling it as a particle under constant acceleration.

$$v_f^2 = v_i^2 + 2a(x_f - x_i) = 0 + 2a(d - 0) = 2ad$$

$$v_f = \sqrt{2ad} = \sqrt{2\left(\frac{qE}{m}\right)d} = \boxed{\sqrt{\frac{2qEd}{m}}}$$



(B) Find the speed of the particle at Ⓑ by modeling it as a nonisolated system in terms of energy.

$$W = \Delta K$$

$$F_e \Delta x = K_{Ⓑ} - K_{Ⓐ} = \tfrac{1}{2}mv_f^2 - 0 \rightarrow v_f = \sqrt{\frac{2F_e \Delta x}{m}}$$

$$v_f = \sqrt{\frac{2(qE)(d)}{m}} = \boxed{\sqrt{\frac{2qEd}{m}}}$$

Example 23.11 An Accelerated Electron AM

An electron enters the region of a uniform electric field as shown in Figure 23.24, with $v_i = 3.00 \times 10^6$ m/s and $E = 200$ N/C. The horizontal length of the plates is $\ell = 0.100$ m.

(A) Find the acceleration of the electron while it is in the elec-

(B) Assuming the electron enters the field at time $t = 0$, find the time at which it leaves the field.

(C) Assuming the vertical position of the electron as it enters the field is $y_i = 0$, what is its vertical position when it leaves the field?

$$a_y = -\frac{eE}{m_e} = -\frac{(1.60 \times 10^{-19}\ \text{C})(200\ \text{N/C})}{9.11 \times 10^{-31}\ \text{kg}} = -3.51 \times 10^{13}\ \text{m/s}^2$$

$$t = \frac{x_f - x_i}{v_x} = \frac{\ell - 0}{v_x} = \frac{0.100\ \text{m}}{3.00 \times 10^6\ \text{m/s}}$$

$$= 3.33 \times 10^{-8}\ \text{s}$$

$$y_f = y_i + v_{yi}t + \tfrac{1}{2}a_y t^2$$

$$y_f = 0 + 0 + \tfrac{1}{2}(-3.51 \times 10^{13}\ \text{m/s}^2)(3.33 \times 10^{-8}\ \text{s})^2$$

$$= -0.019\,5\ \text{m} = -1.95\ \text{cm}$$