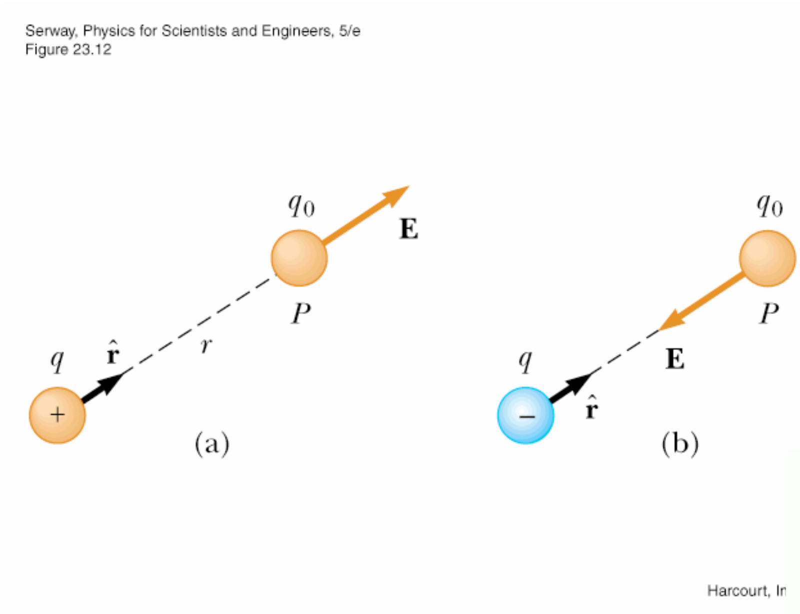


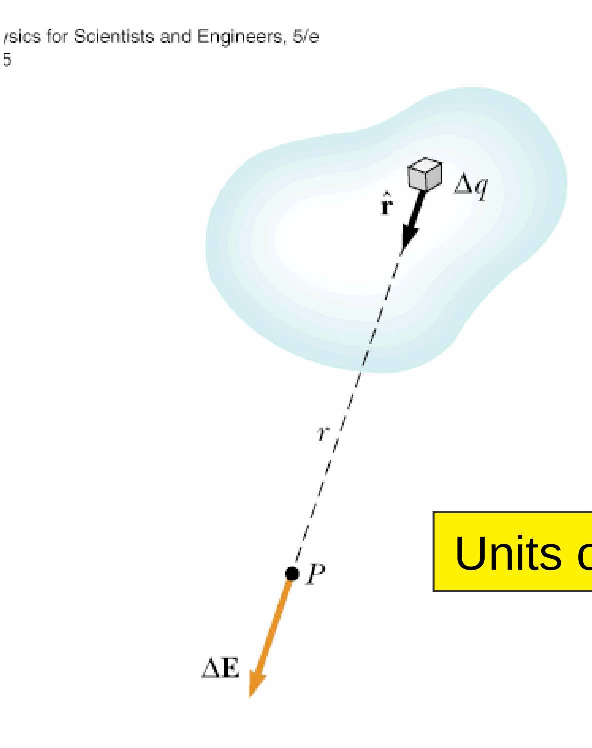
Electric Field due to a charge q

Electric field is the electric force acting on a unit positive charge

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

$$\mathbf{E} = \frac{\mathbf{F}_e}{q_o} \quad \longrightarrow \quad \mathbf{F}_e = \mathbf{E}\, q_o$$

$$\mathbf{E} = k_e \sum_i \frac{q_i}{r_i^2}\,\hat{\mathbf{r}}_\mathbf{i}$$



Units of E: N/C

The elctric field at P due to one element carrying charge Δq is:

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

$$\mathbf{E} = k_e \sum_i \frac{\Delta q_i}{r_i^2}\,\hat{\mathbf{r}}_\mathbf{i}$$

$$\mathbf{E} = k_e \lim_{\Delta q \to 0} \sum_i \frac{\Delta q_i}{r_i^2}\,\hat{\mathbf{r}}_\mathbf{i} = k_e \int \frac{dq}{r^2}\,\hat{\mathbf{r}}$$

Example 23.8

A ring of radius a carries a total charge Q. Calculate the electric field due to the ring at a point P. a distance x from its center, along the central axis perpendicular to the ring.

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Figure 23.17

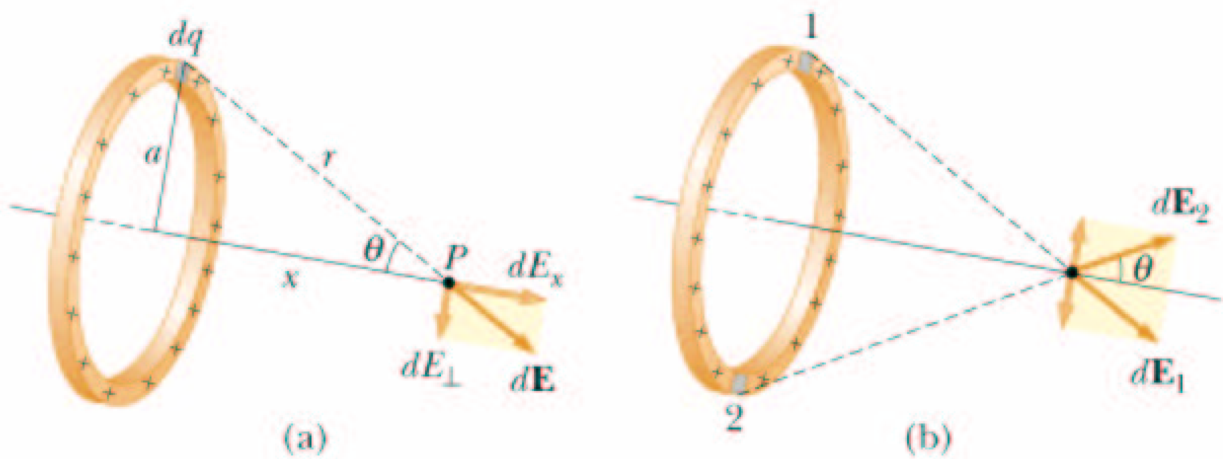

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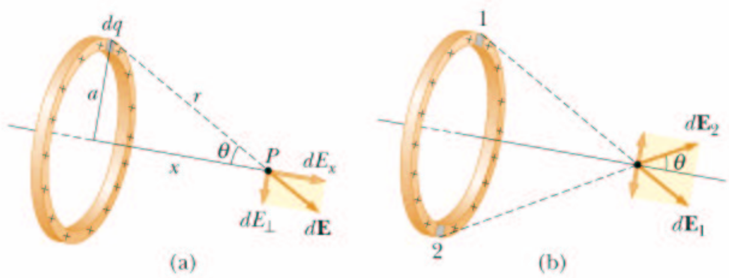
Figure 23.17



27. A uniformly charged ring of radius 10 cm has a charge of 75 μC. Find the electric field on the axis of the ring at 1 cm, 5 cm and 100 cm from the center of the ring

23.27

$$E = \frac{k_e x Q}{(x^2 + a^2)^{3/2}} = \frac{(8.99 \times 10^9)(75.0 \times 10^{-6})x}{(x^2 + 0.100^2)^{3/2}} = \frac{6.74 \times 10^5\, x}{(x^2 + 0.0100)^{3/2}}$$

(a) At $x = 0.0100$ m, $\mathbf{E} = 6.64 \times 10^6\, \mathbf{i}$ N/C = $\boxed{6.64\, \mathbf{i}\ \text{MN/C}}$

(b) At $x = 0.0500$ m, $\mathbf{E} = 2.41 \times 10^7\, \mathbf{i}$ N/C = $\boxed{24.1\, \mathbf{i}\ \text{MN/C}}$

(c) At $x = 0.300$ m, $\mathbf{E} = 6.40 \times 10^6\, \mathbf{i}$ N/C = $\boxed{6.40\, \mathbf{i}\ \text{MN/C}}$

(d) At $x = 1.00$ m, $\mathbf{E} = 6.64 \times 10^5\, \mathbf{i}$ N/C = $\boxed{0.664\, \mathbf{i}\ \text{MN/C}}$

Example 23.9

A disk of radius R has a uniform charge density σ. Calculate the electric field due to the disk at a point P. a distance x from its center, along the central axis perpendicular to the disk.

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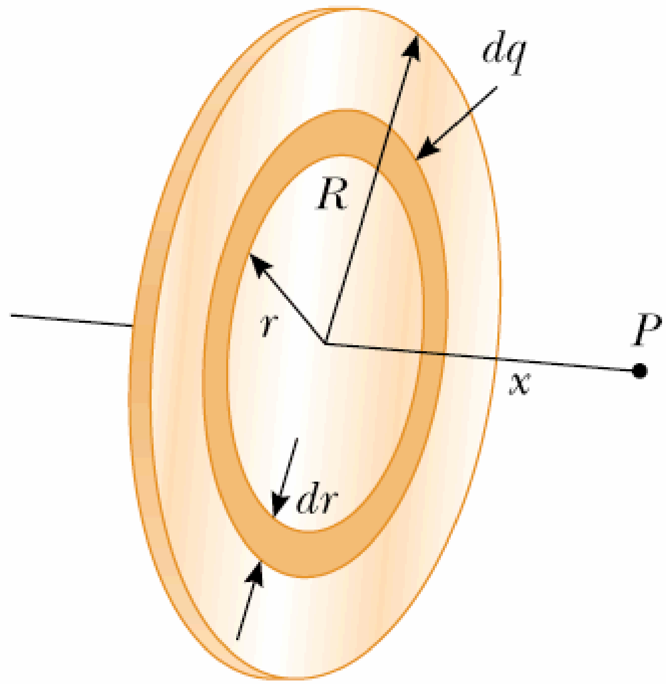
Figure 23.18



Electric Field Lines

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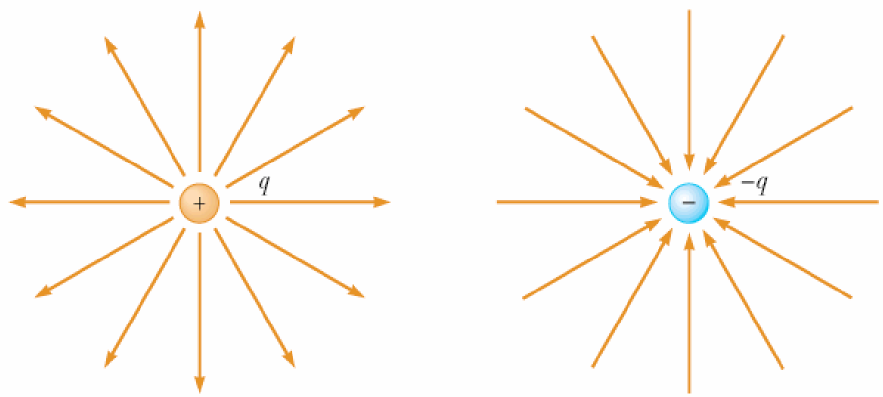
Figure 23.20



(a) (b)

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- Same direction as the electric field vector at any point.
- **E** is tangent to the electric field line
- Number of lines perpendicular to the lines is proportional to the field
  - E small: lines further apart
  - E large: Lines closer
- No two lines can cross

Lines begin on a positive charges and end of negative charges

$1/r^2$ behavior from geometry.

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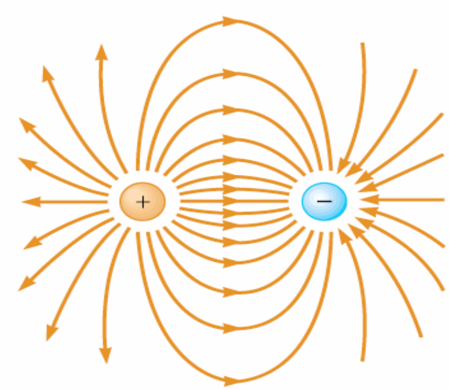
Figure 23.21a



(a)

Harcourt, Inc.

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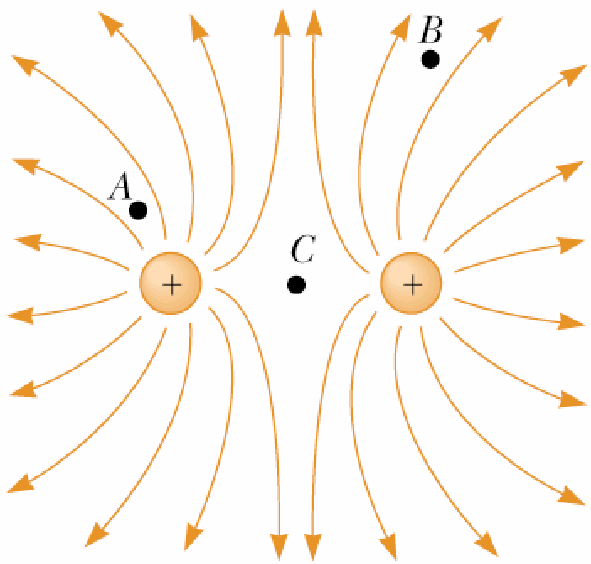
Figure 23.22a



(a)

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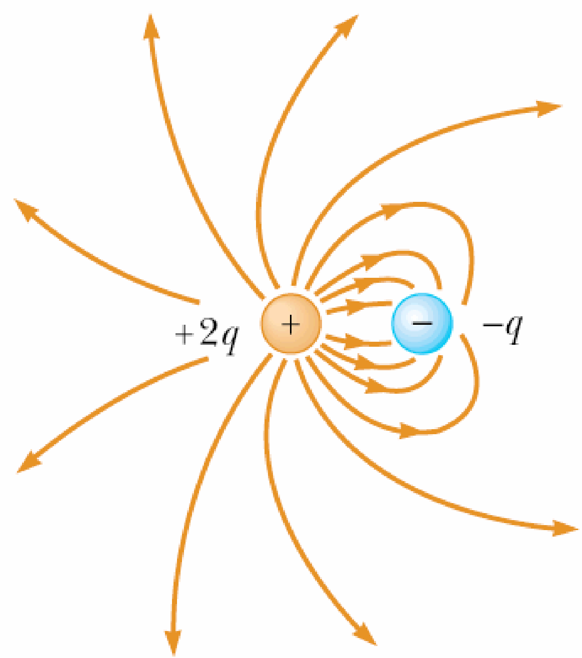
Figure 23.23



Motion of Charged Particles in a Uniform Electric Field

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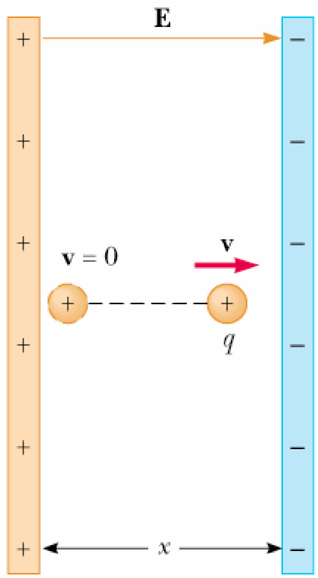
Figure 23.24



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

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

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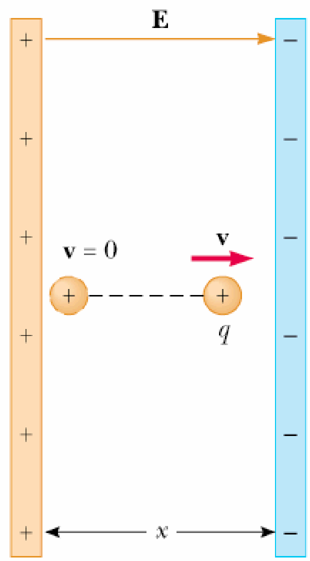
Figure 23.24



43. A proton accelerates from rest in a uniform electric filed of 640 N/C. At some later time its speed has reached 1.2×10^6 m/s.

- find the acceleration of the proton
- how long did it take the the proton to reach this speed ?
- How far has it moved in this time ?
- What is its kinetic energy at this time ?

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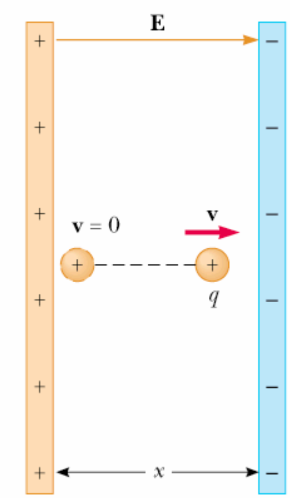
Figure 23.24



23.43 (a) $a = \frac{qE}{m} = \frac{(1.602 \times 10^{-19})(640)}{(1.67 \times 10^{-27})} = \boxed{6.14 \times 10^{10}\ \text{m/s}^2}$

(b) $v = v_i + at$

$1.20 \times 10^6 = (6.14 \times 10^{10})t$

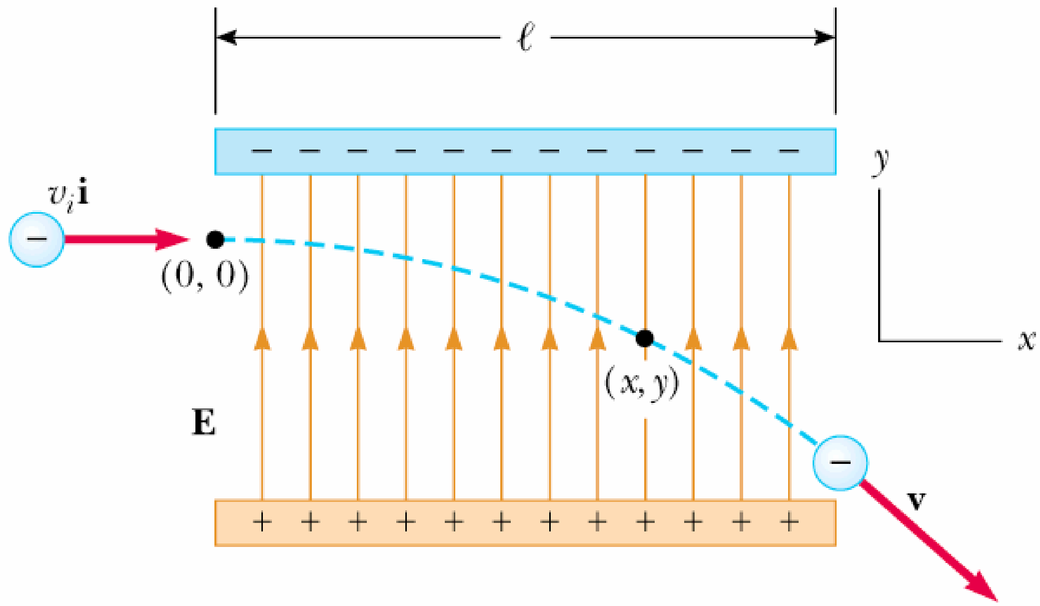
$\boxed{t = 1.95 \times 10^{-5}\ \text{s}}$

(c) $x - x_i = \frac{1}{2}(v_i + v)t$

$x = \frac{1}{2}(1.20 \times 10^6)(1.95 \times 10^{-5}) = \boxed{11.7\ \text{m}}$

(d) $K = \frac{1}{2}mv^2 = \frac{1}{2}(1.67 \times 10^{-27}\ \text{kg})(1.20 \times 10^6\ \text{m/s})^2 = \boxed{1.20 \times 10^{-15}\ \text{J}}$

Serway, Physics for Scientists and Engineers, 5/e
Figure 23.25



rizontal direction. It enters a uniform vertical electric field of 9.6×10^3 N/C. Find:

- The time it takes the proton to travel 5 cm horizontally.
- Its vertical displacement after it has reached 5 cm horizontally
- The vertical and horizontal components of its velocity at this point.

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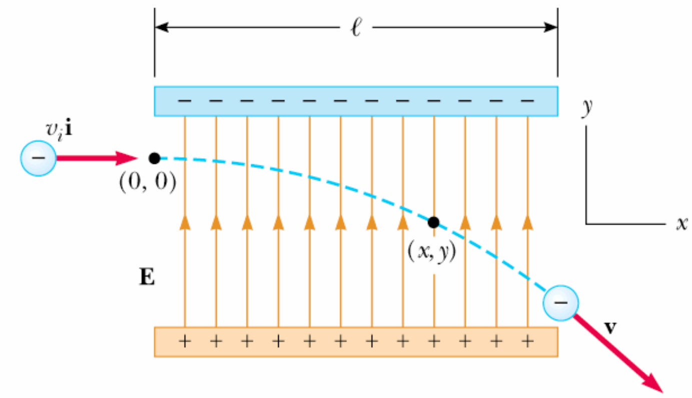
Figure 23.25



23.47 (a) $t = \frac{x}{v} = \frac{0.0500}{4.50 \times 10^5} = 1.11 \times 10^{-7}$ s $=$ $\boxed{111 \text{ ns}}$

(b) $a_y = \frac{qE}{m} = \frac{(1.602 \times 10^{-19})(9.60 \times 10^3)}{(1.67 \times 10^{-27})} = 9.21 \times 10^{11} \text{ m/s}^2$

$y - y_i = v_{yi} t + \frac{1}{2} a_y t^2$

$y = \frac{1}{2}(9.21 \times 10^{11})(1.11 \times 10^{-7})^2 = 5.67 \times 10^{-3} \text{ m} = \boxed{5.67 \text{ mm}}$

(c) $v_x = \boxed{4.50 \times 10^5 \text{ m/s}}$

$v_y = v_{yi} + a_y = (9.21 \times 10^{11})(1.11 \times 10^{-7}) = \boxed{1.02 \times 10^5 \text{ m/s}}$