

43. (a) The electric field is upward in the diagram and the charge is negative, so the force of the field on it is downward. The magnitude of the acceleration is $a = eE/m$, where E is the magnitude of the field and m is the mass of the electron. Its numerical value is

$$a = \frac{(1.60 \times 10^{-19} \text{ C})(2.00 \times 10^3 \text{ N/C})}{9.11 \times 10^{-31} \text{ kg}} = 3.51 \times 10^{14} \text{ m/s}^2 .$$

We put the origin of a coordinate system at the initial position of the electron. We take the x axis to be horizontal and positive to the right; take the y axis to be vertical and positive toward the top of the page. The kinematic equations are

$$x = v_0 t \cos \theta , \quad y = v_0 t \sin \theta - \frac{1}{2} a t^2 , \quad \text{and} \quad v_y = v_0 \sin \theta - a t .$$

First, we find the greatest y coordinate attained by the electron. If it is less than d , the electron does not hit the upper plate. If it is greater than d , it will hit the upper plate if the corresponding x coordinate is less than L . The greatest y coordinate occurs when $v_y = 0$. This means $v_0 \sin \theta - a t = 0$ or $t = (v_0/a) \sin \theta$ and

$$\begin{aligned} y_{\max} &= \frac{v_0^2 \sin^2 \theta}{a} - \frac{1}{2} a \frac{v_0^2 \sin^2 \theta}{a^2} = \frac{1}{2} \frac{v_0^2 \sin^2 \theta}{a} \\ &= \frac{(6.00 \times 10^6 \text{ m/s})^2 \sin^2 45^\circ}{2(3.51 \times 10^{14} \text{ m/s}^2)} = 2.56 \times 10^{-2} \text{ m} . \end{aligned}$$

Since this is greater than $d = 2.00 \text{ cm}$, the electron might hit the upper plate.

- (b) Now, we find the x coordinate of the position of the electron when $y = d$. Since

$$v_0 \sin \theta = (6.00 \times 10^6 \text{ m/s}) \sin 45^\circ = 4.24 \times 10^6 \text{ m/s}$$

and

$$2ad = 2(3.51 \times 10^{14} \text{ m/s}^2)(0.0200 \text{ m}) = 1.40 \times 10^{13} \text{ m}^2/\text{s}^2$$

the solution to $d = v_0 t \sin \theta - \frac{1}{2} a t^2$ is

$$\begin{aligned} t &= \frac{v_0 \sin \theta - \sqrt{v_0^2 \sin^2 \theta - 2ad}}{a} \\ &= \frac{4.24 \times 10^6 \text{ m/s} - \sqrt{(4.24 \times 10^6 \text{ m/s})^2 - 1.40 \times 10^{13} \text{ m}^2/\text{s}^2}}{3.51 \times 10^{14} \text{ m/s}^2} \\ &= 6.43 \times 10^{-9} \text{ s} . \end{aligned}$$

The negative root was used because we want the *earliest* time for which $y = d$. The x coordinate is

$$\begin{aligned} x &= v_0 t \cos \theta \\ &= (6.00 \times 10^6 \text{ m/s})(6.43 \times 10^{-9} \text{ s}) \cos 45^\circ = 2.72 \times 10^{-2} \text{ m} . \end{aligned}$$

This is less than L so the electron hits the upper plate at $x = 2.72 \text{ cm}$.