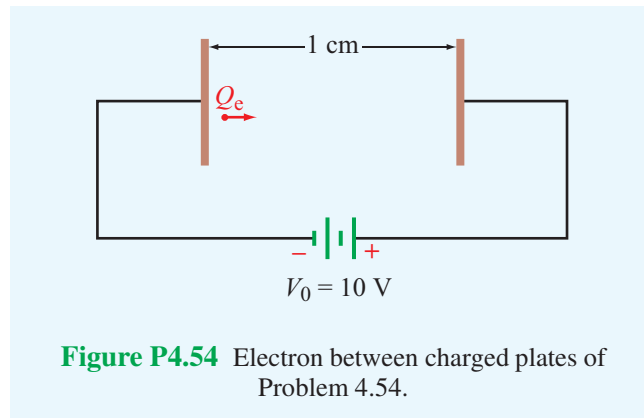


**4.54** An electron with charge  $Q_e = -1.6 \times 10^{-19}$  C and mass  $m_e = 9.1 \times 10^{-31}$  kg is injected at a point adjacent to the negatively charged plate in the region between the plates of an air-filled parallel-plate capacitor with separation of 1 cm and rectangular plates each  $10 \text{ cm}^2$  in area (Fig. P4.54). If the voltage across the capacitor is 10 V, find the following:

- (a) The force acting on the electron.
- (b) The acceleration of the electron.
- (c) The time it takes the electron to reach the positively charged plate, assuming that it starts from rest.



**Solution:**

(a) The electric force acting on a charge  $Q_e$  is given by Eq. (4.14) and the electric field in a capacitor is given by Eq. (4.112). Combining these two relations, we have

$$F = Q_e E = Q_e \frac{V}{d} = -1.6 \times 10^{-19} \frac{10}{0.01} = -1.6 \times 10^{-16} \quad (\text{N}).$$

The force is directed from the negatively charged plate towards the positively charged plate.

(b)

$$a = \frac{F}{m} = \frac{1.6 \times 10^{-16}}{9.1 \times 10^{-31}} = 1.76 \times 10^{14} \quad (\text{m/s}^2).$$

(c) The electron does not get fast enough at the end of its short trip for relativity to manifest itself; classical mechanics is adequate to find the transit time. From classical mechanics,  $d = d_0 + u_0 t + \frac{1}{2} a t^2$ , where in the present case the start position is  $d_0 = 0$ , the total distance traveled is  $d = 1 \text{ cm}$ , the initial velocity  $u_0 = 0$ , and the acceleration is given by part (b). Solving for the time  $t$ ,

$$t = \sqrt{\frac{2d}{a}} = \sqrt{\frac{2 \times 0.01}{1.76 \times 10^{14}}} = 10.7 \times 10^{-9} \text{ s} = 10.7 \quad (\text{ns}).$$