

7. A pair of oppositely charged parallel plates are separated by 5.33 mm. A potential difference of 600 V exists between the plates. (a) What is the magnitude of the electric field strength between the plates? (b) What is the magnitude of the force on an electron between the plates? (c) How much work must be done on the electron to move it to the negative plate if it is initially positioned 2.90 mm from the positive plate?

Solution

(a) A uniform electric field, directed perpendicular to the plates, exists in the region between the plates and exerts a constant force $F = qE$ on a charged particle in this region. When the particle moves a distance d parallel to the field, going from one plate to the other, the work done by the field is $W = Fd \cos 0^\circ = qEd$. Thus, the magnitude of the change in the potential energy of the particle is $|\Delta PE| = W = qEd$ and the magnitude of the potential difference between the plates is

$$|\Delta V| = \frac{|\Delta PE|}{q} = \frac{qEd}{q} = Ed$$

For the given set of plates, $|\Delta V| = 600 \text{ V}$ and $d = 5.33 \times 10^{-3} \text{ m}$. Therefore, the magnitude of the electric field between the plates is

$$E = \frac{|\Delta V|}{d} = \frac{600 \text{ V}}{5.33 \times 10^{-3} \text{ m}} = 1.13 \times 10^5 \text{ V/m} = 1.13 \times 10^5 \text{ N/C} \quad \diamond$$

(b) The magnitude of the force on an electron located between the plates is

$$F = |q|E = eE = (1.60 \times 10^{-19} \text{ C})(1.13 \times 10^5 \text{ N/C}) = 1.80 \times 10^{-14} \text{ N} \quad \diamond$$

(c) The displacement of the electron as it moves from the initial position to the negative plate is

$$s = d - 2.90 \text{ mm} = 5.33 \text{ mm} - 2.90 \text{ mm} = 2.43 \text{ mm}$$

An applied force with magnitude $F = eE = 1.80 \times 10^{-14} \text{ N}$, directed toward the negative plate, must be used to offset the influence of the field and move the electron without acceleration. The work done by the applied force as the electron is moved to the negative plate is

$$W = F s \cos 0^\circ = (1.80 \times 10^{-14} \text{ N})(2.43 \times 10^{-3} \text{ m})(1.00) = 4.38 \times 10^{-17} \text{ J} \quad \diamond$$