Solutions to Exercise Problems — Class-2 — Summer-2025

Incepting Ideas (2)

Steps to follow:
Given parameters:

$$
\begin{aligned}
v_0 &= 5.00 \times 10^{8}\,\mathrm{cm\,s^{-1}} = 5.00 \times 10^{8} \times 10^{-2}\,\mathrm{m\,s^{-1}} = 5.00 \times 10^{6}\,\mathrm{m\,s^{-1}} \\
E &= 1.00 \times 10^{3}\,\mathrm{N\,C^{-1}} \\
q &= -1e = 1.60 \times 10^{-19}\,\mathrm{C} \quad \text{(electron)} \\
m &= 9.11 \times 10^{-31}\,\mathrm{kg}
\end{aligned}
$$

(a) Distance to stop: The electron decelerates under the force:

$$
\begin{aligned}
F &= qE \\
\Rightarrow a &= \frac{q}{m}E.
\end{aligned}
$$

This acceleration would actually be a deceleration since the field stops the electron's motion momentarily. Use the equation of motion:

$$
\begin{aligned}
v^2 &= v_0^2 + 2a\Delta d \quad \text{with } v = 0 \\
\Delta d &= -\frac{v_0^2}{2a} = -\frac{v_0^2}{2 \cdot \frac{-e}{m}E} = \frac{mv_0^2}{2eE} \\
\Delta d &= \frac{(9.11 \times 10^{-31}\,\mathrm{kg})(5.00 \times 10^{6}\,\mathrm{m\,s^{-1}})^2}{2 \cdot (1.60 \times 10^{-19}\,\mathrm{C})(1.00 \times 10^{3}\,\mathrm{N\,C^{-1}})} = 0.0713\,\mathrm{m}.
\end{aligned}
$$

(b) Time to stop:

$$
\begin{aligned}
v &= v_0 + at \\
\Rightarrow t &= \frac{-v_0}{a} = \frac{-v_0}{\frac{-e}{m}E} = \frac{mv_0}{eE} \\
t &= \frac{(9.11 \times 10^{-31}\,\mathrm{kg})(5.00 \times 10^{6}\,\mathrm{m\,s^{-1}})}{(1.60 \times 10^{-19}\,\mathrm{C})(1.00 \times 10^{3}\,\mathrm{N\,C^{-1}})} = 2.85 \times 10^{-5}\,\mathrm{s}
\end{aligned}
$$

(c) Energy lost in 8.00 mm spanning field:
Kinetic energy lost in distance $d_{\text{new}} = 8.00\,\mathrm{mm} = 8.00 \times 10^{-3}\,\mathrm{m}$:

$$
\begin{aligned}
\Delta K &= \frac{1}{2}m\left(v^2 - v_0^2\right) \\
&= \frac{1}{2}m\left(\left[\sqrt{v_0^2 + 2a\Delta d_{\text{new}}}\right]^2 - v_0^2\right) \\
&= \frac{1}{2}m\left(v_0^2 + 2a\Delta d_{\text{new}} - v_0^2\right) \\
&= ma\Delta d_{\text{new}} \\
&= m \cdot \frac{q}{m}E\Delta d_{\text{new}} \\
&= qEd_{\text{new}} \\
&= -eEd_{\text{new}} \\
&= -\left(1.60 \times 10^{-19}\,\mathrm{C} \cdot 1.00 \times 10^{3}\,\mathrm{N\,C^{-1}} \cdot 8.00 \times 10^{-3}\,\mathrm{m}\right) \\
&= -1.28 \times 10^{-18}\,\mathrm{J}
\end{aligned}
$$

The negative sign indicates there has been a loss in kinetic energy.
Fraction lost:

$$
\begin{aligned}
\frac{|\Delta K|}{K_i} &= \frac{eEd_{\text{new}}}{\frac{1}{2}mv_0^2} = \frac{2eEd}{mv_0^2} \\
&= \frac{2 \cdot (1.60 \times 10^{-19}\,\text{C}) \cdot (1.00 \times 10^{3}\,\text{N}\,\text{C}^{-1}) \cdot (8.00 \times 10^{-3}\,\text{m})}{(9.11 \times 10^{-31}\,\text{kg})(5.00 \times 10^{6}\,\text{m}\,\text{s}^{-1})^2} \\
&= 0.112 \\
&\approx 11.2\%.
\end{aligned}
$$

Incepting Ideas (3-Q1)

Steps to follow:
Given parameters:

$$
\begin{aligned}
d &= 2.0\,\text{cm} = 2.0 \times 10^{-2}\,\text{m} \\
t &= 1.5 \times 10^{-8}\,\text{s} \\
q &= 1.60 \times 10^{-19}\,\text{C} \quad \text{(electron)} \\
m &= 9.11 \times 10^{-31}\,\text{kg}
\end{aligned}
$$

(a) Final speed:
Use the kinematic equation:

$$
\begin{aligned}
\Delta d &= \frac{1}{2}at^2 \\
\Rightarrow a &= \frac{2d}{t^2} \\
&= \frac{2 \cdot 2.0 \times 10^{-2}\,\text{m}}{(1.5 \times 10^{-8}\,\text{s})^2} \\
&= 1.78 \times 10^{14}\,\text{m}\,\text{s}^{-2} \\
v &= at \\
&= \left(1.78 \times 10^{14}\,\text{m}\,\text{s}^{-2}\right) \cdot \left(1.5 \times 10^{-8}\,\text{s}\right) \\
&= 2.67 \times 10^{6}\,\text{m}\,\text{s}^{-1}
\end{aligned}
$$

(b) Electric field magnitude:

$$
\begin{aligned}
F &= ma = qE \\
\Rightarrow E &= \frac{ma}{q} \\
&= \frac{(9.11 \times 10^{-31}\,\text{kg}) \cdot (1.78 \times 10^{14}\,\text{m}\,\text{s}^{-2})}{1.60 \times 10^{-19}\,\text{C}} \\
&= 1013\,\text{N}\,\text{C}^{-1}
\end{aligned}
$$

Incepting Ideas (3-Q2)

Steps to follow:
Given:

$$
\begin{aligned}
a &= 1.80 \times 10^{9}\,\text{m}\,\text{s}^{-2} \\
q &= 1.60 \times 10^{-19}\,\text{C} \quad \text{(electron)} \\
m &= 9.11 \times 10^{-31}\,\text{kg}
\end{aligned}
$$

(a) Magnitude of the electric field:

$$\begin{aligned}\vec{E} &= \frac{m\vec{a}}{q} \\ &= \frac{(-9.11\times10^{-31}\,\mathrm{kg})\cdot(1.80\times10^{9}\,\mathrm{m\,s^{-2}})\hat{\imath}}{1.60\times10^{-19}\,\mathrm{C}} \\ &= -10.25\,\mathrm{N\,C^{-1}}\hat{\imath}\end{aligned}$$

Since the electron is negatively charged and accelerates **eastward**, or the $\hat{\imath}$ direction, the electric field must be directed **westward**, or $-\hat{\imath}$ (opposite to the acceleration direction of a negative charge).

Ink Drop Deflection in Electric Field

Incepting Ideas (4)

Steps to follow:
Given:

$$\begin{aligned}m &= 1.3\times10^{-10}\,\mathrm{kg} \\ Q &= 1.5\times10^{-13}\,\mathrm{C} \quad \text{(negative)} \\ v_x &= 18\,\mathrm{m\,s^{-1}} \\ L &= 1.6\,\mathrm{cm} = 1.6\times10^{-2}\,\mathrm{m} \\ E &= 1.4\times10^{6}\,\mathrm{N\,C^{-1}}\end{aligned}$$

(a) Vertical deflection:
Time to cross the plates:

$$t = \frac{L}{v_x} = \frac{1.6\times10^{-2}\,\mathrm{m}}{18\,\mathrm{m\,s^{-1}}} = 8.89\times10^{-4}\,\mathrm{s}$$

Electric force (upward):

$$F = QE \quad \text{(note: upward because Q is negative)}$$

Vertical acceleration:

$$a_y = \frac{F}{m} = \frac{QE}{m} = \frac{(1.5\times10^{-13}\,\mathrm{C})(1.4\times10^{6}\,\mathrm{N\,C^{-1}})}{1.3\times10^{-10}\,\mathrm{kg}} = 1.615\times10^{3}\,\mathrm{m\,s^{-2}}$$

Vertical displacement:

$$\begin{aligned}y - y_0 &= \frac{1}{2}a_y t^2 \\ &= \frac{1}{2}(1.615\times10^{3}\,\mathrm{m\,s^{-2}})\cdot(8.89\times10^{-4}\,\mathrm{s})^2 \\ &= 0.637\,\mathrm{mm}\end{aligned}$$

(b) Velocity at far edge:
Far edge means on the other side of the plate.
Vertical velocity:

$$\begin{aligned}v_y &= a_y t \\ &= (1.615\times10^{3}\,\mathrm{m\,s^{-2}})\cdot(8.89\times10^{-4}\,\mathrm{s}) \\ &= 1.435\,\mathrm{m\,s^{-1}}\end{aligned}$$

Velocity vector (unit vector notation):

$$\begin{aligned}\vec{v} &= v_x\hat{\imath} + v_y\hat{\jmath} \\ &= (-18\,\hat{\imath} + 1.435\,\hat{\jmath})\,\mathrm{m\,s^{-1}}\end{aligned}$$

v_x remains unchanged since $a_x = 0$, according to the question.