Physics 30 – Lesson 17
Parallel Plates

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Practice problems

1. a. To find acceleration we use the principles involving forces.

$\vec{F}_E = q\left|\vec{E}\right|$ combined with $\vec{F} = m\vec{a}$

$$q\left|\vec{E}\right| = m\vec{a}$$

$$\left|\vec{E}\right| = \frac{\Delta V}{\Delta d}$$

$$q\frac{\Delta V}{\Delta d} = m\vec{a}$$

$$\vec{a} = \frac{q\Delta V}{m\Delta d}$$

$$\vec{a} = \frac{(1.60\times10^{-19}C)(8000V)}{(1.67\times10^{-27}kg)(5.0\times10^{-3}m)}$$

$$\boxed{\vec{a} = 1.53\times10^{14}\ \mathrm{m/s^2}}$$

b. To find speed we use the principle of conservation of energy.

$$\Delta E_p = \Delta E_k$$

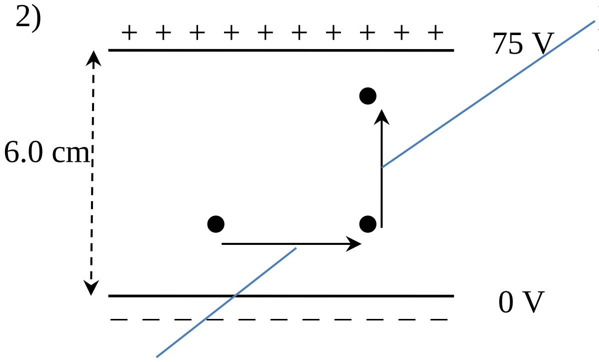
$$q\Delta V = \tfrac{1}{2}mv^2$$

$$v = \sqrt{\frac{2q\Delta V}{m}}$$

$$v = \sqrt{\frac{2(1.60\times10^{-19}C)(8000V)}{(1.67\times10^{-27}kg)}}$$

$$\boxed{v = 1.24\times10^{6}\ \mathrm{m/s}}$$

2)



B. Moving the proton 3.0 cm is perpendicular to the plates – the change in potential is

$$\Delta V = \left(\frac{3.0cm}{6.0cm}\right) \times 75V = 37.5V$$

$$W = \Delta E = q\Delta V$$

$$W = 1.60 \times 10^{-19} C(37.5V)$$

$$\boxed{W = 6.0 \times 10^{-18} J}$$

A. Moving the proton parallel to the plates – since there is no change in potential, no work is done.

C. Potential difference is 75 V

$$\Delta E_p = \Delta E_k$$

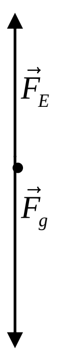
$$q\Delta V = \tfrac{1}{2} mv^2$$

$$v = \sqrt{\frac{2q\Delta V}{m}}$$

$$v = \sqrt{\frac{2(1.60 \times 10^{-19} C)(75V)}{(1.67 \times 10^{-27} kg)}}$$

$$\boxed{v = 1.2 \times 10^5 \, {}^{m}\!/\!_{s}}$$

3.



$$\vec{a} = +2.90 \, {}^{m}\!/\!_{s^2}$$
$$d = 0.0350m$$
$$V = 792V$$
$$m = 5.70 \times 10^{-16} kg$$

$$\vec{F}_{net} = \vec{F}_E + \vec{F}_g$$

$$m\vec{a} = q\left|\vec{E}\right| + m\vec{g}$$

$$q = \frac{m\vec{a} - m\vec{g}}{\left|\vec{E}\right|}$$

$$q = \frac{m\vec{a} - m\vec{g}}{\frac{V}{d}}$$

$$q = \frac{dm(\vec{a} - \vec{g})}{V}$$

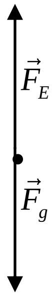
$$q = \frac{0.0350m(5.70 \times 10^{-16} kg)\left[(+2.90 \, {}^{m}\!/\!_{s^2}) - (-9.81 \, {}^{m}\!/\!_{s^2})\right]}{792V}$$

$$\boxed{q = 3.2 \times 10^{-19} C}$$

$$n_{e^-} = \frac{3.2 \times 10^{-19} C}{1.60 \times 10^{-19} C}$$

$$\boxed{n_{e^-} = 2e^-}$$

4.



$$\vec{F}_{NET} = \vec{F}_E + \vec{F}_g$$
$$0 = q\left|\vec{E}\right| - mg$$
$$q\left|\vec{E}\right| = mg$$
$$\frac{qV}{d} = mg$$
$$q = \frac{mgd}{V}$$
$$q = \frac{5.63\times10^{-15}kg(9.81\,{}^{m}/_{s^2})(0.040m)}{4.6\times10^{3}V}$$
$$\boxed{q = 4.8\times10^{-19}C}$$

Assignment

1) /3

$$\left|\vec{E}\right| = \frac{V}{d}$$
$$\left|\vec{E}\right| = \frac{450V}{0.020m}$$
$$\boxed{\left|\vec{E}\right| = 2.3\times10^{4}\,{}^{V}/_{m}}$$

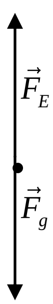
2) /3

$$V = \left|\vec{E}\right|d$$
$$V = (2.5\times10^{3}\,{}^{N}/_{C})(0.080m)$$
$$\boxed{V = 200V}$$

3) /3

$$d = \frac{V}{\left|\vec{E}\right|}$$
$$d = \frac{600V}{1.2\times10^{4}\,{}^{N}/_{C}}$$
$$\boxed{d = 0.050\,m}$$

4) /4



$$\vec{F}_{NET} = \vec{F}_E + \vec{F}_g$$
$$0 = q\left|\vec{E}\right| - mg$$
$$q\left|\vec{E}\right| = mg$$
$$\frac{qV}{d} = mg$$

$$q = \frac{mgd}{V}$$
$$q = \frac{2.6\times10^{-5}kg(9.81\,{}^{m}/_{s^2})(0.0050m)}{270V}$$
$$\boxed{q = 4.70\times10^{-19}C}$$

$$q = 4.70\times10^{-19}C$$
$$q = \frac{4.70\times10^{-19}C}{1.60\times10^{-19}\,{}^{C}/_{e^-}}$$
$$\boxed{q = \pm3e^-}$$

5)

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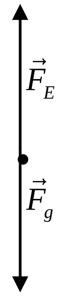

$$\vec{F}_{NET} = \vec{F}_E + \vec{F}_g$$
$$0 = q\left|\vec{E}\right| - mg$$
$$q\left|\vec{E}\right| = mg$$
$$\frac{qV}{d} = mg$$

$$V = \frac{mgd}{q}$$
$$V = \frac{0.10\times10^{-3}kg(9.81\,{}^{m}\!/\!_{s^2})(0.25m)}{5.0\times10^{-6}C}$$
$$\boxed{V = 49V}$$

6)

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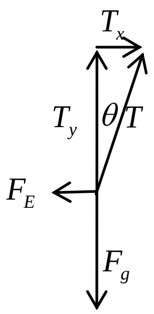
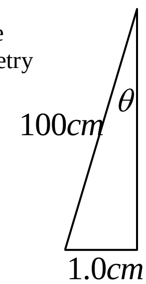


The forces acting on the ball are T, F_E and F_g and the net force acting on the ball is 0. Therefore, the x component of T equals F_E and the y component equals F_g.

We may calculate the angle from the geometry of the string.

$$\theta = \sin^{-1}\frac{1.0}{100}$$
$$\theta = 0.573^\circ$$



a)

$$\left|\vec{E}\right| = \frac{V}{d}$$
$$\left|\vec{E}\right| = \frac{420V}{0.10m}$$
$$\left|\vec{E}\right| = 4200\,{}^{V}\!/\!_{m}$$
$$\boxed{\left|\vec{E}\right| = 4.2\times10^{3}\,{}^{N}\!/\!_{C}}$$

b)

$$T_y = F_g$$
$$T\cos\theta = mg$$
$$T = \frac{mg}{\cos\theta}$$
$$T = \frac{3.0\times10^{-14}kg(9.81\,{}^{m}\!/\!_{s^2})}{\cos(0.573^\circ)}$$
$$\boxed{T = 2.9\times10^{-3}N}$$

c)

$$F_E = T_x$$
$$F_E = T\sin\theta$$
$$F_E = 2.9\times10^{-3}N\sin(0.573^\circ)$$
$$\boxed{F_E = 2.9\times10^{-5}N}$$

d)

$$F_E = q\left|\vec{E}\right|$$
$$q = \frac{F_E}{\left|\vec{E}\right|}$$
$$q = \frac{2.9\times10^{-5}N}{4.2\times10^{3}\,{}^{N}\!/\!_{C}}$$
$$\boxed{q = 7.0\times10^{-9}C}$$

7) a)

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$$V = 300V$$
$$d = 0.040m$$
$$q = 1.60\times10^{-19}C$$
$$m = 9.11\times10^{-31}kg$$

$$\Delta E_p = \Delta E_k$$
$$q\Delta V = \tfrac{1}{2}mv^2$$
$$v = \sqrt{\frac{2q\Delta V}{m}}$$
$$v = \sqrt{\frac{2(1.60\times10^{-19}C)(300V)}{(9.11\times10^{-31}kg)}}$$
$$\boxed{v = 1.0\times10^{7}\ m/s}$$

b)

$$\Delta E = 0 \therefore \boxed{v = 1.0\times10^{7}\ m/s}$$

c)

The electron gained 300 V of potential in the first potential difference. Therefore, it will require 300 V to stop the electron. The electron will stop at the 300 V point in the second potential difference.

$$\frac{300V}{500V} = \frac{x}{4.0\,cm}$$
$$x = \frac{300V}{500V}4.0\,cm$$
$$x = 2.4\,cm$$

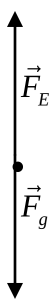
stops at $4.0cm$ - $2.4cm$ = $\boxed{1.6cm \text{ from Z}}$

d) Goes back the same path, but opposite work is done.

$$\therefore v_i = v_f = 0$$

8)

/4



$$\vec{a} = 0 \rightarrow F_E = F_g$$
$$q\left|\vec{E}\right| = F_g$$
$$q = \frac{F_g}{\left|\vec{E}\right|}$$
$$q = \frac{3.84\times10^{-15}N}{1.2\times10^{4}\ N/C}$$
$$\boxed{q = 3.20\times10^{-19}C}$$

9)

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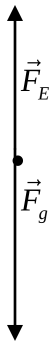

$\vec{a} = -2.50\,{}^{m}\!/\!_{s^2}$

$d = 0.0100m$

$V = 538V$

$m = 3.50 \times 10^{-15} kg$

$$\vec{F}_{net} = \vec{F}_E + \vec{F}_g$$

$$m\vec{a} = q\left|\vec{E}\right| + m\vec{g}$$

$$q = \frac{m\vec{a} - m\vec{g}}{\left|\vec{E}\right|}$$

$$q = \frac{m\vec{a} - m\vec{g}}{\frac{V}{d}}$$

$$q = \frac{dm(\vec{a} - \vec{g})}{V}$$

$$q = \frac{0.0100m(3.5 \times 10^{-15} kg)\left[(-2.50\,{}^{m}\!/\!_{s^2}) - (-9.81\,{}^{m}\!/\!_{s^2})\right]}{538V}$$

$$\boxed{q = 4.76 \times 10^{-19} C}$$

10)

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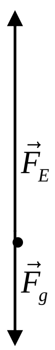

$\vec{a} = +5.20\,{}^{m}\!/\!_{s^2}$

$d = 0.0150m$

$V = ?$

$m = 9.36 \times 10^{-15} kg$

$q = 1.60 \times 10^{-19} C$

$$\vec{F}_{net} = \vec{F}_E + \vec{F}_g$$

$$m\vec{a} = q\left|\vec{E}\right| + m\vec{g}$$

$$\left|\vec{E}\right| = \frac{m\vec{a} - m\vec{g}}{q}$$

$$\frac{V}{d} = \frac{m\vec{a} - m\vec{g}}{q}$$

$$V = \frac{dm(\vec{a} - \vec{g})}{q}$$

$$V = \frac{0.0150m(9.36 \times 10^{-15} kg)\left[(+5.20\,{}^{m}\!/\!_{s^2}) - (-9.81\,{}^{m}\!/\!_{s^2})\right]}{1.60 \times 10^{-19} C}$$

$$\boxed{V = 1.32 \times 10^{4} V}$$

11)

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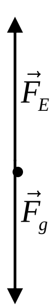


$$\vec{a} = 0 \rightarrow F_E = F_g$$

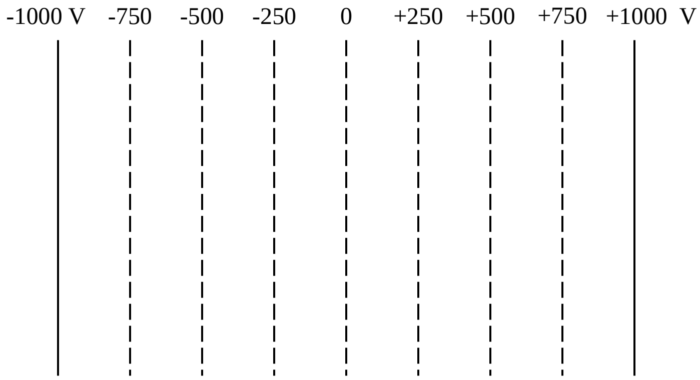
$$q\left|\vec{E}\right| = mg$$

$$q = \frac{mg}{\left|\vec{E}\right|}$$

$$q = \frac{7.20 \times 10^{-16} kg(9.81\,{}^{m}\!/\!_{s^2})}{2.2 \times 10^{4}\,{}^{V}\!/\!_{m}}$$

$$\boxed{q = 3.20 \times 10^{-19} C}$$

12)



$$V = \left|\vec{E}\right| d$$
$$V = (1.0\times10^{5}\ {}^{N}\!/_{C})(0.020m)$$
$$V = 2000V$$

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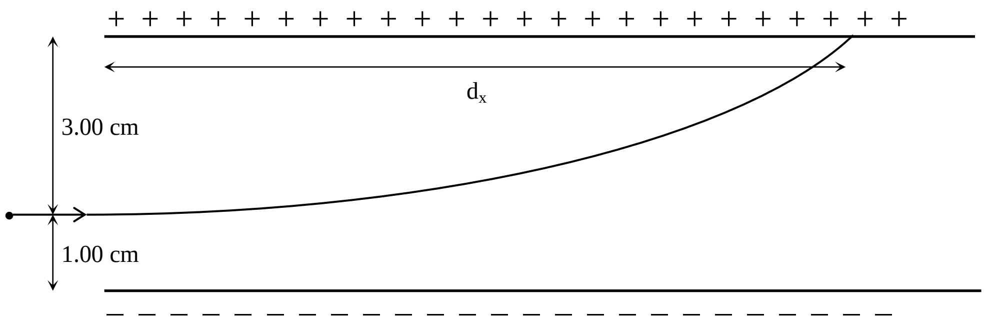
midway V=1000 V

$$E_k = W$$
$$\tfrac{1}{2}mv^2 = Vq$$
$$v = \sqrt{\frac{2Vq}{m}}$$
$$v = \sqrt{\frac{2(1000V)(1.60\times10^{-19}C)}{1.67\times10^{-27}kg}}$$
$$\boxed{v = 4.4\times10^{5}\ {}^{m}\!/_{s}}$$

13)



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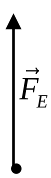
The electrons enter the electric field and experience a vertical force due to repulsion from the negative plate and attraction to the positive plate. **Since the electric field between the plates is uniform (i.e. the same throughout the region) the resulting vertical acceleration will be uniform**. However, the original horizontal motion will **not** be affected since there is no force acting horizontally on the electrons. Therefore they will accelerate toward the positive plate while maintaining their horizontal velocity.

We can solve for the horizontal distance by treating the electron like a projectile from Physics 20. Note that the initial vertical velocity is zero ($v_i = 0$) and the acceleration due to gravity (–9.81 m/s^2) is negligible compared to the acceleration due to the electric field (+5.2689 × 10^{14} m/s^2).



vertical

$$\vec{F}_{net} = \vec{F}_E$$

$$m\vec{a} = q\left|\vec{E}\right|$$

$$m\vec{a} = \frac{qV}{d}$$

$$\vec{a} = \frac{qV}{md}$$

$$\vec{a} = +\frac{(1.60\times10^{-19}C)(120V)}{(9.11\times10^{-31}kg)(4.00\times10^{-2}m)}$$

$$\vec{a} = +5.2689\times10^{14}\ ^{m}/_{s^2}$$

$$\Delta\vec{d} = \vec{v}_1\Delta t + \tfrac{1}{2}\vec{a}\Delta t^2$$

$$\Delta\vec{d} = \tfrac{1}{2}\vec{a}\Delta t^2$$

$$t = \sqrt{\frac{2\Delta\vec{d}}{\vec{a}}}$$

$$t = \sqrt{\frac{2(3.00\times10^{-2}m)}{5.2689\times10^{14}\ ^{m}/_{s^2}}}$$

$$t = 1.067\times10^{-8}s$$

horizontal

$$d_x = v_x\Delta t$$

$$d_x = (6.50\times10^{6}\ ^{m}/_{s})(1.067\times10^{-8}s)$$

$$\boxed{d_x = 6.94\,cm}$$