

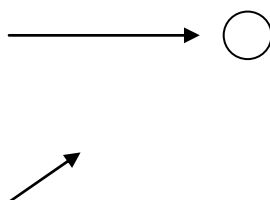
Answers to Coursebook questions – Chapter 5.2

- 1 **a** See **Figure 2.4** on page 291 in *Physics for the IB Diploma*.
- b** See **Figure 2.6** on page 291 in *Physics for the IB Diploma*.
- c** Something like **Figure 2.6** but the place in the middle where the lines appear to be making a square should be moved a bit to the left.
- d** Essentially **Figure 2.5** on page 291 in *Physics for the IB Diploma* (it does not matter that we say three times in *Physics for the IB Diploma* that the difference between 2 and 3 cannot really be seen).
- 2 Because if they were not there would a component of the electric field along the surface. This would cause electrons to move in the conducting surface contrary to the assumption that we are dealing with electrostatics in which charges cannot move.

3 **a**



b



- 4 **a–c** The force is the same everywhere inside the plates since the electric field is uniform and equal to $E = \frac{V}{d} = \frac{500}{0.10} = 5.00 \times 10^3 \text{ V m}^{-1}$.
The force is everywhere $F = eE = 1.6 \times 10^{-19} \times 5.00 \times 10^3 = 8.0 \times 10^{-16} \text{ N}$.
- d** The potential increases by $\frac{500}{10} = 50$ volt for every cm moved up from the bottom plate. So the potential difference between the two given points is 300 V. Hence the work done is $W = e\Delta V = 1.6 \times 10^{-19} \times 300 = 4.8 \times 10^{-17} \text{ J}$.

5 The force is $F = qE = 1.6 \times 10^{-19} \times 100 = 1.6 \times 10^{-17} \text{ N}$ and the acceleration is

$$a = \frac{F}{m} = \frac{1.6 \times 10^{-17}}{9.1 \times 10^{-31}} = 1.8 \times 10^{13} \text{ ms}^{-2}.$$

6 $F = eE \Rightarrow E = \frac{F}{e} = \frac{3.0 \times 10^{-5}}{5.0 \times 10^{-6}} = 6.0 \text{ N C}^{-1}.$

7 The magnitude of each of the fields produced at P is:

$$E = \frac{kQ}{r^2} = \frac{8.99 \times 10^9 \times 2.00 \times 10^{-6}}{\left(\sqrt{0.05^2 + 0.30^2}\right)^2} = 1.95 \times 10^5 \text{ N C}^{-1}.$$

The vertical components of the electric fields will cancel out, leaving only the horizontal components.

The horizontal component is

$$E_x = E \cos \theta = E \frac{d}{\sqrt{d^2 + \frac{a^2}{4}}} = 1.95 \times 10^5 \times \frac{0.30}{\sqrt{\frac{0.10^2}{4} + 0.30^2}} = 1.92 \times 10^5 \text{ N C}^{-1}.$$

The net field is then directed horizontally to the right and has magnitude $2 \times 1.92 \times 10^5 = 3.84 \times 10^5 \text{ N C}^{-1}.$

8 The 2 electric fields are $E_1 = 1.95 \times 10^5 \text{ NC}^{-1}$ and $E_2 = 3.90 \times 10^5 \text{ NC}^{-1}.$

Adding vectorially by taking components gives

$$E_x = 1.92 \times 10^5 \text{ NC}^{-1} + 3.85 \times 10^5 \text{ NC}^{-1} = 5.77 \times 10^5 \text{ NC}^{-1} \text{ and}$$

$$E_y = 0.3156 \times 10^5 \text{ NC}^{-1} - 0.6313 \times 10^5 \text{ NC}^{-1} = -0.3157 \times 10^5 \text{ NC}^{-1}.$$

And so $E = 5.78 \times 10^5 \text{ NC}^{-1}$, $\theta = \arctan -\frac{0.3157 \times 10^5}{5.77 \times 10^5} \approx -3.1^\circ.$

9 a $W = q\Delta V = 5.0 \times 100 = 500 \text{ V}.$

b $W = q\Delta V = 5.0 \times 200 = 1000 \text{ V}.$

c It would be the same, but only the initial and final points count, not the path joining them.

10 a Using $eV = \frac{1}{2}mv^2$ we find $v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 100}{9.1 \times 10^{-31}}} = 5.9 \times 10^6 \text{ m s}^{-1}.$

b

$$v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 100}{1.67 \times 10^{-27}}} = 1.4 \times 10^5 \text{ m s}^{-1}$$

11 The net electric field has magnitude $E = \sqrt{115^2 + 125^2} = 170 \text{ N C}^{-1}.$

Its direction is $\theta = \arctan \frac{115}{125} \approx 180^\circ - 42.6^\circ = 137.4^\circ.$

- 12 a and b** These points are inside the conducting sphere, so the electric field is zero there.

c

$$E = \frac{kQ}{R^2} = \frac{8.99 \times 10^9 \times 4.0 \times 10^{-6}}{(15.0 \times 10^{-2})^2} = 1.6 \times 10^6 \text{ N C}^{-1}$$

d At 20 cm.

$$E = 1.6 \times 10^6 \times \left(\frac{15}{20}\right)^2 = 9.0 \times 10^5 \text{ N C}^{-1}$$

- 13 a** The electric force is downwards, i.e. in the direction of the field, and so the charge has to be positive.

b Before the field is turned on, $kx_0 = mg$. With the field on, $k2x_0 = mg + qE$.

Hence, $2mg = mg + qE$ and so $E = \frac{mg}{q}$.

c Calling the extension **from equilibrium** x we have that the net force on the particle is $F_{\text{net}} = k(2x_0 + x) - qE - mg = kx$. The force is upward, i.e. opposite the displacement and proportional to displacement. Hence SHM oscillations take place.

d The net upward force is the same as what we would have without the electric field, so the period is unaffected by its presence.

- 14 a** The electric field is $E = \frac{kQ}{(d/4)^2} - \frac{k9Q}{(3d/4)^2} = 0$.

b When it is displaced to the right, the force will be directed to the left and so the mass will move back. It will overshoot the equilibrium position of **a** and move past it to the left. Once there, the net force will now be directed to the right and so the mass will keep oscillating.

c To decide if the oscillations are SHM we must find the net force on the charge and see that it is opposite and proportional to the displacement: let x be the displacement to the right (measured from the position of equilibrium in **a**). The net force is $F = qE = \frac{kQq}{(\frac{d}{4} + x)^2} - \frac{9kQq}{(\frac{3d}{4} - x)^2}$ which is directed to the left but is not proportional to x , so the oscillations are not SHM.

d Displacing a negative charge to the right results in a net force to the right, i.e. there will not be any oscillations.

15 a The net force has been found in **Q14** to be $F = \frac{kQq}{(\frac{d}{4} + x)^2} - \frac{9kQq}{(\frac{3d}{4} - x)^2}$.

b The force can be rewritten as

$$F = \frac{kQq}{\frac{d^2}{16}(1 + \frac{4x}{d})^2} - \frac{9kQq}{\frac{9d^2}{16}(1 - \frac{4x}{3d})^2} = \frac{16kQq}{d^2} \left(\frac{1}{(1 + \frac{4x}{d})^2} - \frac{1}{(1 - \frac{4x}{3d})^2} \right).$$

Applying the given approximation,

$$F \approx \frac{16kQq}{d^2} \left((1 - 2\frac{4x}{d}) - (1 - 2\frac{4x}{3d}) \right) = \frac{16kQq}{d^2} \left(-\frac{8x}{d} + \frac{8x}{3d} \right) = -\frac{256kQq}{3d^3}x.$$

c The force is opposite and proportional to the displacement so we will have SHM.

We have for the acceleration $a = -\frac{256kQq}{3md^3}x$ and so $\omega^2 = \frac{256kQq}{3md^3}$.

The period will be $T = \frac{2\pi}{\omega}$.