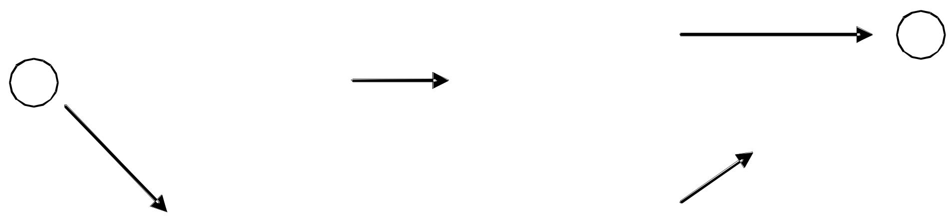
Chapter 5.2

Q1 See figures 2.4 and 2.6.

Q2 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.

Q3



Q4 (a) – (c) The force is the same everywhere inside the plates since the electric field is uniform and equal to $E = \frac{V}{d} = \frac{500}{0.10} = 5.00\times10^3\ \text{V m}^{-1}$. The force is everywhere $F = eE = 1.6\times10^{-19}\times5.00\times10^3 = 8.0\times10^{-16}\ \text{N}$. (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 $W = e\Delta V = 1.6\times10^{-19}\times300 = 4.8\times10^{-17}\ \text{J}$.

Q5 The force is $F = qE = 1.6\times10^{-19}\times100 = 1.6\times10^{-17}\ \text{N}$ and the acceleration is $a = \frac{F}{m} = \frac{1.6\times10^{-17}}{9.1\times10^{-31}} = 1.8\times10^{13}\ \text{m s}^{-2}$.

Q6 $F = eE \Rightarrow E = \frac{F}{e} = \frac{3.0\times10^{-5}}{5.0\times10^{-6}} = 6.0\ \text{N C}^{-1}$.

Q7 The magnitude of each of the fields produced at P is:
$E = \frac{kQ}{r^2} = \frac{8.99\times10^9\times2.00\times10^{-6}}{\left(\sqrt{0.05^2+0.30^2}\right)^2} = 1.95\times10^5\ \text{N C}^{-1}$. The vertical components of the electric fields will cancel out leaving only the horizontal components. The horizontal component is
$E_x = E\cos\theta = E\frac{d}{\sqrt{d^2+\frac{a^2}{4}}} = 1.95\times10^5\times\frac{0.30}{\sqrt{\frac{0.10^2}{4}+0.30^2}} = 1.92\times10^5\ \text{N C}^{-1}$. The net field is then directed horizontally to the right and has magnitude $2\times1.92\times10^5 = 3.84\times10^5\ \text{N C}^{-1}$.

Q8 The 2 electric fields are $E_1 = 1.95\times10^5\,\text{NC}^{-1}$ and $E_2 = 3.90\times10^5\,\text{NC}^{-1}$. Adding vectorially by taking components gives
$E_x = 1.92\times10^5\,\text{NC}^{-1} + 3.85\times10^5\,\text{NC}^{-1} = 5.77\times10^5\,\text{NC}^{-1}$ and
$E_y = 0.3156\times10^5\,\text{NC}^{-1} - 0.6313\times10^5\,\text{NC}^{-1} = -0.3157\times10^5\,\text{NC}^{-1}$.

And so $E = 5.78\times10^5\,\text{NC}^{-1}$, $\theta = \arctan - \dfrac{0.3157\times10^5}{5.77\times10^5} \approx -3.1^\circ$.

Q9 (a) $W = q\Delta V = 5.0\times100 = 500\ \text{V}$. (b) $W = q\Delta V = 5.0\times200 = 1000\ \text{V}$. (c) It would be the same, only the initial and final points count not the path joining them.

Q10 (a) Using $eV = \dfrac{1}{2}mv^2$ we find
$v = \sqrt{\dfrac{2eV}{m}} = \sqrt{\dfrac{2\times1.6\times10^{-19}\times100}{9.1\times10^{-31}}} = 5.9\times10^6\ \text{m s}^{-1}$.
(b) $v = \sqrt{\dfrac{2eV}{m}} = \sqrt{\dfrac{2\times1.6\times10^{-19}\times100}{1.67\times10^{-27}}} = 1.4\times10^5\ \text{m s}^{-1}$.

Q11 The net electric field has magnitude $E = \sqrt{115^2 + 125^2} = 170\ \text{N C}^{-1}$. Its direction is $\theta = \arctan\dfrac{115}{125} \approx 180^\circ - 42.6^\circ = 137.4^\circ$.

Q12 (a) and (b) These points are inside the conducting sphere so the electric field is zero there. (c) $E = \dfrac{kQ}{R^2} = \dfrac{8.99\times10^9\times4.0\times10^{-6}}{(15.0\times10^{-2})^2} = 1.6\times10^6\ \text{N C}^{-1}$. (d) At 20 cm,
$E = 1.6\times10^6\times\left(\dfrac{15}{20}\right)^2 = 9.0\times10^5\ \text{NC}^{-1}$.

Q13 (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 $E = \dfrac{mg}{q}$. (c) Calling the extension *from equilibrium x* we have that the net force on the particle is $F_{net} = k(2x_0 + x) - qE - mg = kx$. 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.

Q14 (a) The electric field is $E = \dfrac{kQ}{(d/4)^2} - \dfrac{k9Q}{(3d/4)^2} = 0$. (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 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.

Q15 (a) The net force has been found in problem 14 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,

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