Solutions

Each answer shows the steps, then the **result**.

2.1

- the force between two **point charges** is **proportional to the product of the charges**
- and **inversely proportional to the square of their separation**

2.2

- $1/(4\pi\varepsilon_0) = 9.0 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$

2.3

- they **repel**

3.1 C

- $F \propto 1/r^2$, so doubling r makes F **one quarter**

3.2

- $F = Q_1 Q_2/(4\pi\varepsilon_0 r^2)$

$$F = \frac{(9.0 \times 10^9 \text{ N m}^2 \text{ C}^{-2})(2.0 \times 10^{-9} \text{ C})(3.0 \times 10^{-9} \text{ C})}{(0.040 \text{ m})^2} = \mathbf{3.4 \times 10^{-5}} \text{ N}$$

3.3

- $F = Q^2/(4\pi\varepsilon_0 r^2)$

$$F = \frac{(9.0 \times 10^9 \text{ N m}^2 \text{ C}^{-2})(5.0 \times 10^{-9} \text{ C})^2}{(0.020 \text{ m})^2} = \mathbf{5.6 \times 10^{-4}} \text{ N}$$

- **repulsive** (like charges)

3.4

(a) the electric force between two **point charges** is proportional to the **product of the charges**

- and inversely proportional to the **square of their separation**

(b) $F = Q_1 Q_2/(4\pi\varepsilon_0 r^2)$

$$F = (8.99 \times 10^9 \text{ N m}^2 \text{ C}^{-2}) \frac{(2 \times 1.60 \times 10^{-19} \text{ C})(1.60 \times 10^{-19} \text{ C})}{(2.6 \times 10^{-11} \text{ m})^2} \approx \mathbf{1.4 \times 10^{-7}} \text{ N}$$

(c) the electric force is the centripetal force: $mv^2/r = F$

$$v = \sqrt{\frac{Fr}{m}} = \sqrt{\frac{(1.36 \times 10^{-7} \text{ N})(2.6 \times 10^{-11} \text{ m})}{9.11 \times 10^{-31} \text{ kg}}} = \mathbf{2.0 \times 10^6} \text{ m s}^{-1}$$

(d) $T = 2\pi r/v$

$$T = \frac{2\pi(2.6 \times 10^{-11}\ \text{m})}{2.0 \times 10^{6}\ \text{m s}^{-1}} = \mathbf{8.2 \times 10^{-17}}\ \text{s}$$

(e) $F_{\text{grav}} = GMm/r^2$

$$F_{\text{grav}} = \frac{(6.67 \times 10^{-11}\ \text{N m}^2\,\text{kg}^{-2})(6.6 \times 10^{-27}\ \text{kg})(9.11 \times 10^{-31}\ \text{kg})}{(2.6 \times 10^{-11}\ \text{m})^2} = 5.9 \times 10^{-46}\ \text{N}$$

$$\frac{1.4 \times 10^{-7}\ \text{N}}{5.9 \times 10^{-46}\ \text{N}} = \mathbf{2 \times 10^{38}}$$

- gravity is utterly negligible on this scale, so a model of the atom can ignore it and keep only the electric force