Solutions

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

2.1

- Coulomb's law:

$$F = k\frac{q_1 q_2}{r^2} = (8.99 \times 10^9\ \text{N m}^2\,\text{C}^{-2})\,\frac{(2.0 \times 10^{-6}\ \text{C})^2}{(0.30\ \text{m})^2}$$

- $F = \mathbf{0.40}$ N, repulsive

2.2

- the electrostatic force (by far)

2.3

- charge comes in whole multiples of e, $q = Ne$:

$$N = \frac{q}{e} = \frac{8.0 \times 10^{-19}\ \text{C}}{1.6 \times 10^{-19}\ \text{C}}$$

- $N = \mathbf{5}$

3.1 C

- $1/r^2$.

3.2 B

- vector superposition of all the forces.

3.3

(a)

- Coulomb's law for one outer charge, $r = 0.10$ m:

$$F = k\frac{q_1 q_2}{r^2} = (8.99 \times 10^9\ \text{N m}^2\,\text{C}^{-2})\,\frac{(3.0 \times 10^{-6}\ \text{C})(1.0 \times 10^{-6}\ \text{C})}{(0.10\ \text{m})^2}$$

- $F = \mathbf{2.7}$ N, away from that charge

(b)

- zero – the two outer charges push the middle charge with equal forces in opposite directions, which cancel

3.4

(a)

- known: $q_1 = 2.0 \times 10^{-6}$ C, $q_2 = 2.0 \times 10^{-6}$ C (magnitudes), $r = 0.050$ m; Coulomb's law in a vacuum:

$$F_0 = k\frac{|q_1 q_2|}{r^2} = (8.99 \times 10^9\ \text{N m}^2\,\text{C}^{-2})\,\frac{(2.0 \times 10^{-6}\ \text{C})(2.0 \times 10^{-6}\ \text{C})}{(0.050\ \text{m})^2}$$

- $F_0 = \mathbf{14}$ N (14.4 N), attractive

(b)

- in a material the permittivity is $\varepsilon = \kappa\varepsilon_0$, so the force is divided by κ:

$$F = \frac{F_0}{\kappa} = \frac{14.4\ \text{N}}{2.5}$$

- $F = \mathbf{5.8}$ N

(c)

- the oil's molecules polarise: their ends nearest each sphere carry opposite charge, which partly cancels the field of each sphere at the other

3.5

(a)

- on the **outer surface** of the sphere

(b)

- **zero**
- charges in a conductor move freely; any field inside would push them until they rearrange to cancel it, so in equilibrium the field inside the metal is zero