Solutions

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

2.1

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

2.2

- $E \propto 1/r^2$ (inverse-square)

2.3

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

$$E = \frac{(9.0 \times 10^9\ \mathrm{N\ m^2\ C^{-2}})(5.0 \times 10^{-9}\ \mathrm{C})}{(0.10\ \mathrm{m})^2} = \mathbf{4.5 \times 10^3}\ \mathrm{N\ C^{-1}}$$

3.1 B

- $E \propto 1/r^2$

3.2

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

$$E = \frac{(9.0 \times 10^9\ \mathrm{N\ m^2\ C^{-2}})(8.0 \times 10^{-9}\ \mathrm{C})}{(0.020\ \mathrm{m})^2} = \mathbf{1.8 \times 10^5}\ \mathrm{N\ C^{-1}}$$

3.3

- similarity: both follow an **inverse-square** law (radial field around a point source)
- difference: the electric force can be **attractive or repulsive**, but gravity is **always attractive**

3.4

(a) potential is the work done per unit positive charge bringing a test charge from infinity

- a positive charge **repels** the test charge, so external work must be done **on** it to bring it closer, making the potential positive everywhere around the charge

(b) at Q the field points **radially away** from the sphere, i.e. directly outwards along the line from the centre

- inside the metal the field is **zero** — the charge resides on the surface and the interior is field-free

(c) $E = 0$ from $x = 0$ to $x = R$, drawn along the axis

- a **discontinuous jump** to the maximum E_0 at $x = R$
- then an inverse-square decay for $x > R$, falling to $E_0/4$ at $2R$ and $E_0/16$ at $4R$

(d) outside the sphere it behaves as a point charge at its centre, so $E \propto 1/x^2$

- at $2R$ the field is $E_0/4$

(e) by symmetry the fields cancel at the **midpoint**, $3R$ from each centre

- the potentials, being scalars, **add** there, so the potential is not zero — it is smaller than at either surface but still positive