B

Homework: CCF2

How many excess electrons must be distributed uniformly within the volume of an isolated plastic sphere 26.0 cm in diameter to produce an electric field of magnitude 1500 N/C just outside the surface of the sphere?

[*We identify that the sphere is uniformly charged, and spherically symmetric. We can show e.g., by example 22.9 in Y&F, that the electric field outside the sphere is the same as for a point charge of the same charge located at the centre of the sphere.*]

We want to find the number of excess electrons inside the sphere, which can be obtained by dividing the excess charge Q *just outside* of the sphere by the charge of an electron, q_e. The electric field at a separation r due to a point charge is

$$E = \frac{kQ}{r^2}, \tag{B.1}$$

so the excess charge is

$$Q = \frac{Er^2}{k}. \tag{B.2}$$

We are given the *diameter* so the radius $R = 0.130$ cm, so the excess charge

is

$$Q = \frac{1500 \times 0.130^2}{8.99 \times 10^9} = 2.82 \times 10^{-9}\ \text{C}. \tag{B.3}$$

The number of electrons is thus

$$n = \frac{Q}{q_e} = \frac{2.82 \times 10^{-9}}{1.60 \times 10^{-19}} = 1.79 \times 10^{10}. \tag{B.4}$$

[*The most common mistake was using 26.0 cm as the radius and not squaring the radius.*]

What is the electric field at a point 14.5 cm outside the surface of the sphere?

We are considering a point 14.5 cm away from the *surface* of the sphere, so the total radius away from the centre of the sphere is $r = R + 0.145 = 0.275$ m.

We know that the electric field attenuates as $1/r^2$, so the electric field at the position r is

$$E = \frac{kQ}{r^2} = \frac{8.99 \times 10^9 \times 2.83 \times 10^{-9}}{0.275^2} = 3.35 \times 10^2\ \text{NC}^{-1} \tag{B.5}$$

[*There were no issues with this question for those who answered (a) correctly.*]