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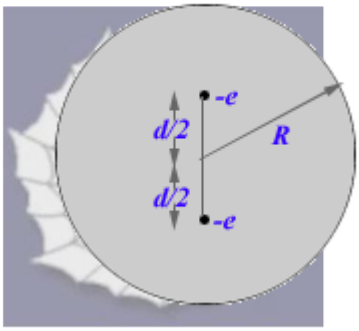
Problem 29.50 (RHK)

In the figure a Thomson model for an atom of helium (Z=2) is shown. Two electrons, at rest, are embedded inside a uniform sphere of positive charge 2e. We have to find the distance d between the electrons so that the configuration is in static equilibrium.



Solution:

In the Thomson model of atom positive charge is assumed to be distributed uniformly in the volume of the atom and electrons are embedded like raisins in a cake. The volume density of charge within the helium atom of radius R is

$$\rho = \frac{2e \times 3}{4\pi R^3} = \frac{3e}{2\pi R^3}.$$

For static equilibrium the resultant force on any of the electrons has to be zero. Forces on any of the two electrons will be the inward radial force of attraction due to the positive charge contained in a sphere of radius, $d/2$, i.e.

$$q = \frac{4\pi}{3} \times \frac{d^3}{8} \times \rho = \frac{\pi d^3}{6} \times \frac{3e}{2\pi R^3} = \frac{ed^3}{4R^3};$$

and the force of repulsion due to the other electron. Therefore, the condition of equilibrium is

$$\frac{qe}{4\pi\varepsilon_0 \left(d^2/4\right)} = \frac{e^2}{4\pi\varepsilon_0 d^2},$$

or

$$\frac{ed^3 e}{4\pi\varepsilon_0 \times 4R^3 \times \left(d^2/4\right)} = \frac{e^2}{4\pi\varepsilon_0 d^2},$$

or

$$d = R.$$