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Problem 30.24 (RHK)

Much of the material comprising Saturn's rings is in the form of tiny dust particles having radii on the order of 1.0 μm. These grains are in a region containing a dilute ionised gas, and they pick up excess electrons. Assuming that the electric potential at the surface of a grain is −400 V, we have to estimate the number of excess electrons it has picked up.

Solution:

Potential on the surface of a charged sphere, charge q, radius, r, is

$$V = \frac{q}{4\pi\varepsilon_0 r}.$$

It is given that the typical radius of a grain in the Saturn's ring is

$r = 1.0 \ \mu\text{m} = 1.0 \times 10^{-6} \ \text{m},$

and that the potential on the surface of a grain is

$V = -400 \ \text{V}.$

Electron charge is $e = 1.6 \times 10^{-19} \ \text{C}.$

Therefore, the number of excess electrons on a grain will be

$$n = \frac{V 4\pi\varepsilon_0 r}{e} = \frac{400 \times 1.0 \times 10^{-6}}{8.99 \times 10^9 \times 1.6 \times 10^{-19}} = 2.78 \times 10^5.$$