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Problem 30.3 (RHK)

A decade before Einstein published his theory of relativity, J.J. Thomson proposed that the electron might be made up of small parts and that its mass is due to the electrical interaction of the parts. Furthermore, he suggested that the energy equals mc^2. *We will make a rough estimate of the electron mass in the following way: we will assume that the electron is composed of three identical parts that are brought in from infinity, and placed at the vertices of an equilateral triangle having sides equal to the classical radius of the electron,* $2.82\times10^{-15}\ \text{m}$. (a) *We will find the total electrical potential energy of this arrangement*. (b) *We will divide it by* c^2 *and compare our result with the accepted electron mass* $\left(9.11\times10^{-31}\ \text{kg}\right)$. *The result improves if more parts are assumed. Today, the electron is thought to be a single, indivisible particle.*

Solution:

As given in the problem we will assume that the electron is composed of an assembly of three equal charges, $-e/3$, placed at the vertices of an equilateral triangle having side equal to the classical radius of the electron, $a = 2.82\times10^{-15}$ m.

The total electric potential energy of this arrangement is

$$U = \frac{1}{4\pi\varepsilon_0}\times\frac{1}{a}\times\left(\frac{e^2}{9}+\frac{e^2}{9}+\frac{e^2}{9}\right) = \frac{1}{4\pi\varepsilon_0}\times\frac{1}{a}\times\frac{e^2}{3}$$

$$= \frac{8.99\times10^9\times\left(1.6\times10^{-19}\right)^2}{2.82\times10^{-15}\times3}\ \text{J} = 2.720\times10^{-14}\ \text{J}$$

$$= 0.17\ \text{MeV}.$$

(b)

Mass equivalent of U is

$$\frac{U}{c^2} = \frac{2.720\times10^{-14}}{\left(3\times10^8\right)^2}\ \text{kg} = 3.02\times10^{-31}\ \text{kg}.$$

We compare it with the rest mass of the electron, which is 9.11×10^{-31} kg, and find

$$\frac{U/c^2}{m_e} = \frac{3.02\times10^{-31}}{9.11\times10^{-31}} = 0.33.$$