

1B-1 Fall 2020: Quiz 4B

Show all your work and use proper units throughout. This quiz is open-book but not open-Chegg and must be completed without help. Please try to write your answers into the boxes. If you submit your work with your own formatting please try to submit the same number of pages as the template (4).

1. The nucleus of an atom can be modeled as spherically symmetric charge distribution with the following volume charge density:

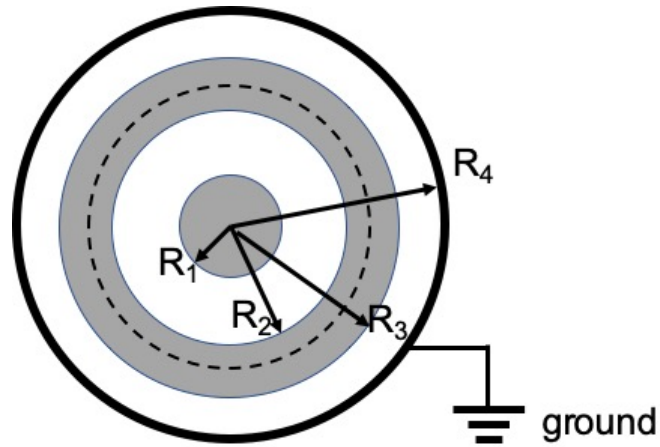
$$\rho_V(r) = \begin{cases} \rho_0(1 - \frac{r}{R}) & \text{if } r \leq R \\ 0 & \text{if } r > R \end{cases}$$

Here ρ_0 is the volume charge density at the center of the nucleus (at $r = 0$) and R is the radius of the nucleus.

a) Calculate the vector electric field everywhere inside the nucleus as a function of position. Express your answer in terms of the total charge Q of the nucleus. *[10 points]*

b) A nucleus can decay by emitting an alpha particle, which consists of two neutrons and two protons (i.e. its mass is $4m_{proton}$ and its charge is $2q_{proton}$). Quantum physics allows the alpha particle to jump to a finite distance $r > R$ outside the nucleus. If the alpha particle starts from rest at $r = 10^{-14}$ m, what is its escape velocity very far from the nucleus? Assume that the charge of the nucleus is $Q = 90q_{proton}$ after it has emitted the alpha particle, and that it is so heavy that it remains at rest. *[8 points]*

2. Consider the spherically symmetric charge configuration shown below. An insulating sphere of homogeneous charge density has a radius R_1 and a charge of $+Q$. It is surrounded by air, which is surrounded by a conducting spherical shell of inner radius R_2 , outer radius R_3 and charge $+2Q$, which is surrounded by air, and finally by a thin conducting shell of radius R_4 . The outermost conducting shell is grounded.



a) What is the charge on the outermost shell? Explain your reasoning. *[2 points]*

b) What is the electric flux through the spherical closed surface shown by the dashed line at $R_2 < r < R_3$? Explain your reasoning. *[2 points]*

c) Qualitatively correct sketch the magnitude of the electric field as a function of radius from $r = 0$ to $R > R_4$. [5 points]



d) What is the vector electric field as a function of r in the region $R_3 < r < R_4$? [3 points]

