Physics 492 homework VI, due Fri Feb 27

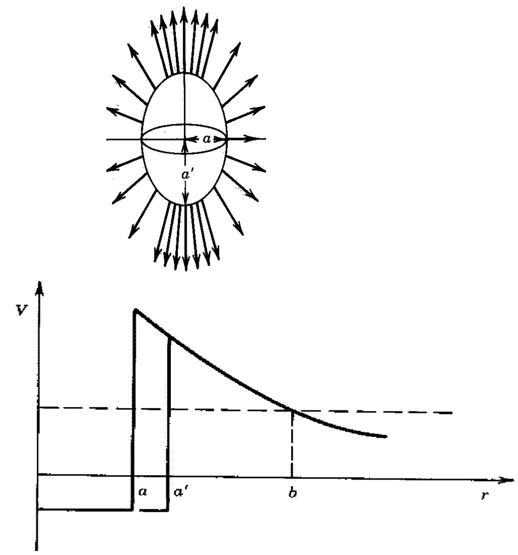
Reading: Chapters 6, 7.1-3

Problems:

1. Use the masses in the Table of Isotopes in the CRC Handbook of Chemistry and Physics (on reserve in Physics Library) or on the Web (http://www.nndc.bnl.gov/nndcscr/masses/MASS_RMD.MAS95) to show that ^{197}Au is nominally unstable with respect to α-decay. Calculate the kinetic energy of an α particle that would be emitted in the decay. (Note: Because of the recoil given to the daughter nucleus, the kinetic energy is slightly less than the Q-value for the decay.) Using the empirical Geiger-Nutall law, $\log_{10} t_{1/2} \simeq a + b\,Q^{-1/2}$, with $a \simeq -1.61\,Z_D^{2/3} - 21.4$ and $b \simeq 1.61\,Z_D$, estimate the half-life for the α-decay of gold. The time in the empirical law is in seconds and the Q-value is in MeV. How does that half-life compare to the age of Universe? How does the Q-value compare to the one obtained in Problem 5.1 from Williams?

2. Use the tunneling formula derived in class, and given in the handout, to justify the empirical Geiger-Nutall law in Problem 1, including the values of the numerical coefficients there. The α-particle velocity inside the parent nucleus may be assumed to take some representative value, such as outside the nucleus or larger. Note that the nuclear Z and A are correlated with each other around the line of stability and approximately proportional to each other for heavy nuclei.

3. Consider the strongly deformed nucleus ^{252}Fm with the deformation parameter $\epsilon = 0.3$. That is, the nucleus is shaped like an ellipsoid of revolution with semimajor axis $a' = R(1+\epsilon)$ and semiminor axis $a = R/(1+\epsilon)^{1/2}$, where $R \simeq r_0\,A^{1/3}$ is the mean radius. Using a potential of the form suggested in the figure below, and following one-dimensional barrier-penetration considerations, estimate the relative probabilities of polar and equatorial emission of α particles.



In a deformed nucleus, α particles escaping from the poles enter the Coulomb barrier at the larger separation a', and must therefore penetrate a lower, thinner barrier. It is therefore more probable to observe emission from the poles than from the equator.

4. A typical induced fission reaction is

$$n + {}^{235}_{92}U \rightarrow {}^{92}_{36}Kr + {}^{142}_{56}Ba + 2n\,.$$

(a) Estimate the mass energy released, using the Weizsäcker semi-empirical mass formula.

(b) Calculate the mass energy released, using the exact atomic masses in the Table of Isotopes.

(c) Calculate the total mass energy, in joules, released when 1 kg of ^{235}U undergoes fission.

Note: nuclear mass = atomic mass – $Z\,m_e$,
1 u = 931.494 MeV/c^2,
mass excess = atomic mass - A×1u.