1. (5 pts) Use the masses in the Table of Isotopes on the Web: http://www.nndc.bnl.gov/amdc/masstables/Ame2003/mass.mas03 to show that $^{197}$Au is nominally unstable with respect to $\alpha$ decay. Calculate the kinetic energy of an $\alpha$ 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.) Use Eq. 6.6 to estimate the half-life for the $\alpha$ decay of gold. 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. (6 pts.) Make a drawing to scale of the Coulomb potential barrier encountered in the $\alpha$ decay of $^{242}$Cm ($Z=96$) for which the decay to the ground state of $^{238}$Pu has a $Q$-value of 6.217 MeV. Assume $R = r_0A^{1/3}$ with $r_0 = 1.5$ fm to account for the diffuseness of the nuclear surface. Show also the Coulomb-plus-centrifugal barrier for the $\ell = 2$ decay to the first excited state at 44 keV excitation energy. Use an approximation analogous to Eq. 6.1 or the formula given in lecture to estimate the reduction of the decay probability caused by the centrifugal barrier, and correspondingly estimate the ratio of the $\alpha$ branching ratio to first excited state over that of the ground state of $^{238}$Pu. (Don’t forget to reduce the $Q$ value for decays to the excited state.) How does it compare to the actual ratio of 1/3?

3. (6 pts.) A typical induced fission reaction is $n + ^{235}_{92}U \rightarrow ^{92}_{56}Kr + ^{142}_{56}Ba + 2n$

(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 listed above.

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


5. (6 pts) Consider the strongly deformed nucleus $^{252}$Fm with the deformation parameter $\varepsilon = 0.3$. That is, the nucleus is shaped like an ellipsoid of revolution with semi-major axis $a' = R(1+\varepsilon)$ and semi-minor axis $a = R/(1+\varepsilon)^{1/2}$, where $R = r_0A^{1/3}$ with $r_0 = 1.5$ fm is the mean radius. Using a potential of the form suggested in the figure above, and following one-dimensional barrier-penetration considerations, estimate the relative probabilities of polar and equatorial emission of $\alpha$ particles.

6. (4 pts) The $\alpha$ decay of $^{244}$Cm populates a $0^+$ excited state in $^{240}$Pu at 0.861 MeV with an intensity of $1.6 \times 10^{-4}$ %, while the $0^+$ ground state is populated with an intensity of 76.7%. Estimate the ratio between these decay intensities from the theory of $\alpha$ decay and compare with the experimental value.